

# TM 5-700

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

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## FIELD WATER SUPPLY

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*HEADQUARTERS, DEPARTMENT OF THE ARMY  
OCTOBER 1961*



TECHNICAL MANUAL }  
No. 5-700

HEADQUARTERS,  
DEPARTMENT OF THE ARMY  
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# CHAPTER I

## PURPOSE, SCOPE, AND RESPONSIBILITIES

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### 1. Purpose

This manual is a reference and training guide for engineer personnel engaged in military field water supply in combat zones, occupation areas, and other locations such as disaster areas. It also serves as a planning reference for engineer staffs at all levels. This manual does not cover those aspects of water treatment and inspection for municipal systems.

### 2. Scope

*a. Content.* The manual covers water quality and characteristics, water treatment processes, the establishment and development of water points, use of existing facilities, and contamination of water by chemical, biological, and radiological agents and industrial waste. Also covered are the basic steps in water purification, field tests, equipment, and establishing and developing water sources under arctic and desert conditions. The discussion of water points includes reconnaissance, field water sources, distribution and distribution facilities, and water supply records. Details on operation and maintenance of equipment, which can be found in applicable equipment manuals, are outside the scope of this manual.

*b. Applicability.* This manual is applicable to both nuclear and nonnuclear warfare.

*c. Comments.* Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to Commandant, U.S. Army Engineer School, Fort Belvoir, Va.

### 3. Importance of Water Supply

The soldier's water supply affects his health and general welfare, his combat efficiency, and his morale. Without water, the

soldier is out of action in a day or two. In extremely hot areas, or in cases of extreme physical exertion, his limit is 16 hours. Since water must be potable and palatable, as well as available, the Army's water purification equipment must be highly efficient and, at the same time, highly mobile.

#### 4. Requirements

The Army requires large quantities of treated water. Table I (app. II) shows the per capita daily water requirements for soldiers in combat, on the march, and in bivouac, camps, or hospitals, and the daily average requirements for vehicles. Table II indicates the quantity and quality of water needed for construction equipment. Standards of quality require that drinking water be free of disease-producing organisms, harmful contaminants, and objectionable color, odor, and taste. All untreated water is considered unsafe until approved by an Army Medical Service officer.

#### 5. Responsibilities

Unit commanders, the Corps of Engineers, the Army Medical Service, the Chemical Corps, the Quartermaster Corps, and the Transportation Corps have certain responsibilities for field water supply.

*a. Unit Commanders.* All unit commanders have the responsibility to provide units and individuals of their command with the required amount of safe drinking water at all times. They must take measures to insure an understanding of the perils of drinking unsafe water by all personnel of the command, and enforce strict discipline so the men will—

- (1) Drink treated or approved water only.
- (2) Not waste purified water.
- (3) Protect water sources by good sanitary habits.

*b. Corps of Engineers.* The Corps of Engineers is responsible for making available a supply of treated water for all purposes to all Army units. It is responsible for the design, procurement, installation, operation, and maintenance of water supply equipment. Engineer personnel perform water reconnaissance, develop sources, and transport water to distribution points. The Corps is also responsible for making initial qualitative tests for chemical, biological, and radiological agents in water. Engineers coordinate their responsibilities with the Army Medical Service and Chemical Corps personnel to insure that the water is safe to drink.

*c. Army Medical Service.* The Army Medical Service is responsible for the detection and quantitative analysis of chemical, biological, and radiological agents in water. The Army Medical Service inspects water points and sources, makes tests, and is

the final authority as to whether a water source can be used. It insures that water is properly treated and, in cooperation with the Corps of Engineers and Chemical Corps, makes studies and recommendations on the design, selection, and operation of water purification equipment.

*d. Chemical Corps.* The Chemical Corps is responsible for the development of specialized kits to determine the degree of chemical contamination in water. In addition, it assists, advises, and coordinates with the Corps of Engineers and the Army Medical Service on matters concerning the design, selection, and operation of water purification equipment.

*e. Quartermaster Corps.* The Quartermaster Corps is responsible for the procurement, storage, and issue of individual and small unit water storage containers (such as canteens and 5-gallon cans) and emergency sterilization supplies of the type used by individuals.

*f. Transportation Corps.* The Transportation Corps is responsible for the rail and overwater transportation of water in bulk. It is also responsible for establishing and operating boiler-feed water processing points required for Transportation Corps rail and marine operations.

## CHAPTER 2

### WATER RECONNAISSANCE

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#### 6. Purpose and Responsibility

Water reconnaissance is a special type of engineer reconnaissance made to gather information about water sources. Reconnaissance for water sources includes preliminary planning, ground reconnaissance, and reports; all three phases must be completed before the best source can be selected. Primary responsibility for water supply is vested in the S4, who coordinates reconnaissance activities with the S2.

#### 7. Water Sources

a. A satisfactory water source is one with a natural supply of water of sufficient quantity to supply all needs of using troops (attached or supported) and of such quality that it can be readily purified by available equipment. A water source developed for military use is called a water point.

b. Water sources are classified as follows:

- (1) Surface water: streams, lakes, and rivers.
- (2) Ground water: wells and springs.
- (3) Sea water.
- (4) Snow and ice.

c. The types of water sources most frequently found in various climates are listed below:

- (1) Humid temperate climate: surface and ground water.
- (2) Tropical climate: surface water, ground water, and minor sources.
- (3) Arid climate: ground water and minor sources.
- (4) Coral islands: ground and sea water.
- (5) Arctic climate: surface water, ice, and snow.

d. Possible water sources include not only surface, ground, and sea water but also minor sources such as snow, ice, rain, and vegetation. However, this manual is concerned primarily with surface water sources which can be made potable by field units with equipment listed in applicable TOE's. A detailed discussion on wells, ground water, and sea water can be found in TM 5-297 and TM 5-2068.

## 8. Preliminary Planning

*a. Field Reports.* The most important and reliable sources of information on water resources in an area are the field reports which contain summaries based on recent observations. The source of such information in division or higher units is the G2, who has reconnaissance reports, results of prisoner-of-war and native interrogations, tactical data, and other records. In the engineer battalion, the S2 is the source of this information. Higher echelon intelligence studies can be obtained through higher headquarters.

*b. Map Studies.* All existing maps and aerial photographs of the area of operation should be studied before the actual ground reconnaissance. In the use of maps, it should be understood that military maps are frequently incomplete and inaccurate. This is especially true in regard to the "works of man." Therefore, heavy reliance should not be placed on maps; a ground reconnaissance must always be made. Keeping their limitations in mind, the following information can be obtained from a study of maps:

- (1) Maps are especially valuable for locating surface water sources. Places where a road crosses or runs near a stream or pond are always possible water points. A study of drainage lines is helpful in areas where no streams are indicated.
- (2) Water sources downstream of human habitations are subject to contamination. If possible, water points should be selected upstream from villages whether inhabited or abandoned.
- (3) Road nets are best shown on maps. Although the credibility of the information obtained from the map study will depend on the date of the map being used, the information can serve as a basis for determining whether or not the existing road net in a particular area can handle the necessary traffic.

*c. Personnel and Equipment.*

- (1) Personnel selected to perform a water reconnaissance should include at least one qualified water supply specialist. He should be familiar with water treatment processes and know how to produce potable water with available equipment. Equipment carried by personnel should include testing equipment necessary for use in determining water characteristics from test samples.
- (2) Whenever possible, reconnaissance personnel should be accompanied by a representative of the Surgeon. This is particularly desirable in checking the quality of raw water.

*d. Route and Time Schedule.* Before making a ground recon-

naissance, it is important that a route and time schedule be drawn up. This is done by determining from a map study or other source the possible water sources to be reconnoitered. Then, with a map at hand, time should be allotted for travel to and from the sites as well as additional time for any unforeseen events, and for preparation and turn in of the report. After these considerations, the time remaining is the amount left to be divided for coverage of each site. Once the time schedule is set up, the time of arrival and departure for selected points should be written down and the schedule followed closely.

## 9. Ground and Air Reconnaissance

*a. Air Reconnaissance.* When time permits, the actual ground reconnaissance may be preceded by an air reconnaissance. Air reconnaissance, using any type of aircraft, is an effective and generally reliable means for rapidly securing information about water sources over a large area. If used in conjunction with the map study, a visual or photographic air reconnaissance will disclose changes of the terrain not shown on existing maps. While en route to possible sites, the observer should note routes of communications, cover and concealment from enemy observation, and protection from encirclement, infiltration, or attack. The appraisal of the area covered can be confirmed by the ground reconnaissance. If a helicopter is used, the air and ground reconnaissance can be conducted as one. Upon location of a possible site the helicopter can be landed for closer observation and performance of tests. The use of aircraft for reconnaissance is limited by adverse weather conditions.

*b. Ground Reconnaissance.* Although an air reconnaissance is valuable as a general aid in determining possible water sources and other general information, an actual ground observation is the only positive way of getting accurate information from which to select a water point. During the conduct of the ground reconnaissance a sketch of the site properly keyed to a map will prove invaluable. Memory alone is not sufficiently reliable; notes should always be taken. The route and time schedule should be followed closely, since it is better to make a sketchy report than to be late in submission of a more complete report. Command decisions cannot always be delayed until complete information is obtained. Factors to be considered during the ground reconnaissance are—

- (1) *Quantity of water.* When making a reconnaissance, seasonal changes in water quantity can be ignored unless the information is readily available from native sources. Generally it is enough to report "sufficient" or "insufficient" water. Rear-area units charged with constructing permanent installations must check the quantity more

carefully. As flow gages, meters, and related measuring devices are seldom available, quantity data is usually collected by improvised methods. When time permits, a horizontal pipe (table XIX, app. II) can be installed which can accurately measure the quantity of water flowing in a small stream. A less accurate but more rapid method is to measure the average cross-sectional area and average velocity of the stream. The accuracy of this method depends entirely on the care taken by the person making the measurements. (The procedures for calculating the quantity of water (gpm) flowing in a stream by this method are given in par. 6, app. III.)

- (2) *Quality of water.* Water should be of such quality that it can be readily purified with normal field equipment. If test kits are available, the pH value, chlorine demand and the presence of chemical warfare agents can be determined as described in paragraphs 82, 83, 85, 87, and 117 through 124. If kits are not available, valuable information can be obtained by close observation and common sense judgment on the following quality characteristics:
  - (a) Color.
  - (b) Turbidity.
  - (c) Odor.
  - (d) Taste (use with caution).
  - (e) Possible sources of pollution.
  - (f) Condition of vegetation around source; dead or mottled vegetation may indicate the presence of chemical warfare agents.
  - (g) Presence of dead fish, frogs, etc.
- (3) *Routes of communications.* A satisfactory water point must be accessible to both vehicles and personnel. A good road net with turnarounds, cover, and concealment at the water point and an adequate parking area are particularly desirable features. The bearing capacity of roads should be sufficient to withstand the heaviest vehicles under all weather conditions. The water point should be located on a through road whenever possible but main supply routes should be avoided.
- (4) *Site conditions.* Where two or more sites meet the above requirements, selection is based on site conditions. The following considerations are discussed in order of importance:
  - (a) *Drainage.* The site should be on high, porous ground to prevent its becoming excessively muddy or swampy with use. Failure to consider drainage inevitably leads

to serious maintenance problems later. Units moving up to previously occupied water points should carefully check the drainage, as tactical considerations may have forced advance units to disregard this factor.

- (b) *Security*. In addition to cover and concealment, the site should be a safe distance from enemy snipers and artillery and aerial targets. Security against ground attacks and sabotage of storage facilities are also important factors to be considered.
- (c) *Bivouac for personnel*. A satisfactory bivouac area should be provided, since purification unit operators must live near the water point. This area should be near enough so operators not on duty are available in emergencies, yet far enough away to maintain proper sanitation of the water source. The bivouac area must be downstream from the water source.

## 10. Reports

Reconnaissance data should be reported on DA Forms 1711-R (Engineer Reconnaissance Report) and 1712-R (Water Reconnaissance Report) as shown in figures 1, 2, 3, 4, and 5. Reconnaissance reports must be carefully prepared and available on time. The information presented must be legible, clear, complete, and concise. All information should be printed. DA Forms 1711-R and 1712-R will be reproduced locally on 8- by 10½-inch paper.



ENGINEER RECONNAISSANCE REPORT (TM 5-700)				PAGE 1 OF 1 PAGES
TO: <i>CO 32<sup>ND</sup> Engr. Bn</i>		FROM: <i>Hq + Hq Co. 32<sup>ND</sup> Engr. Bn</i>		
FILE NO. <i>HS 47</i>	PARTY LEADER (Name, Grade, Organization) <i>Smith 1<sup>ST</sup> Lt Hq + Hq Co 32<sup>ND</sup> Engr. Bn</i>		PLACE - HOUR - DATE <i>Cg. 187256-070700 OCT.</i>	
REPORT NO. <i>1</i>				
MAPS <i>France &amp; Belgium; 1944; 1:50,000 Sheet 3855 IVNW</i>				
DELIVER TO (Organization, Place, Hour and Date) <i>32<sup>ND</sup> Engr. Bn, St Nicholas, 071100 Oct.</i>				
KEY  ①	OBJECT  W	TIME OBSERVED  0835	WORK ESTIMATE?  YES	<p>ADDITIONAL REMARKS AND SKETCH</p> <p>Quantity: A = 2 sq. ft. V = 30 fpm. Q = 60 cfm, 450 gpm Quality: slight turbidity no odor possible pollution from nearby farms pH = 6.8 Chlorine demand = 2 ppm</p>
				<p><i>Communications: 1-way road with good drainage runs to 1<sup>ST</sup> Inf area. Not used for division supplies. Turnout at wp must be constructed.</i></p> <p><i>Site Conditions: good concealment, no targets in vicinity ground slopes gently from road to stream, good drainage banks, 3' high, sodded. Use access road as parking area. Grove of trees or farmhouse can be used as bivouac for w.p. personnel.</i></p> <p><i>Rating: Excellent w.p. for 1<sup>ST</sup> Inf.</i></p>
ENGINEER WORK ESTIMATE ON OTHER SIDE				
TYPED NAME, GRADE AND ORGANIZATION <i>Norman H. Wells Capt. Hq &amp; Hq 32 Engr Bn</i>				SIGNATURE <i>Norman H. Wells</i>

DA Form 1711-R, 1 Jun 61

Edition of 1 May 56 is obsolete.

Figure 1. Engineer reconnaissance report form—1st page.

ENGINEER WORK ESTIMATE									
LOCATION KEY	DESCRIPTION OF WORK	UNIT REQ'D	HOURS	EQUIPMENT		MATERIALS			
				Type	No.	Hours	Type	Unit	Quantity
①	A. Construct Turnout: 1. Light Clearing & grubbing. 2. Spread Gravel. B. Set up Equipment.	1 Squad	2 hr.	Squad Pioneer Tool Set	1	2 hr.	bank gravel/ (on site)	cu. yd.	3
		WP Team	½ hr.	Mobile Water Purification Unit, 1500 GPH	1				
RECONNAISSANCE REPORT ON OTHER SIDE									

Figure 2. Engineer reconnaissance report form—back of form.

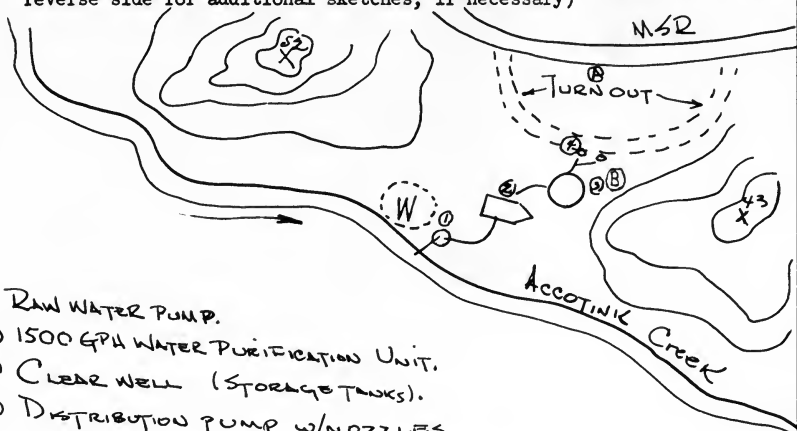
WATER RECONNAISSANCE REPORT (TM 5-700)		DATE 8 Sep 60	PAGE 1 OF 3 PAGES
TITLE NUMBER	REPORT NUMBER 1	REPORTED BY (Name - Grade - Organization) Walker J. Newman, Sfc 86th Eng Bn	
FORWARDED TO S-A, 374 GP			
1. LOCATION OF WATER SOURCE			
MAP Ft Belvoir & Vicinity, 1:25000		COORDINATES 516 723	
2. TYPE OF SOURCE (Check one) <input type="checkbox"/> Other (specify)			LOCAL NAME OF SOURCE
<input checked="" type="checkbox"/> Stream <input type="checkbox"/> Lake <input type="checkbox"/> Pond <input type="checkbox"/> Spring <input type="checkbox"/> Well <input type="checkbox"/> Reservoir			Accotink Creek
3. DATE AND HOUR INSPECTED	4. YIELD		
08 1400 60	IMMEDIATE (gpm) 12500	ULTIMATE (gpm) (Give work estimate) 17,000	108 man hours
5. QUALITY			
COLOR Clear	ODOR None	TASTE Muddy	
TURBIDITY (estimate) Less than 50	pH TEST 7.5	CHLORINE DEMAND TEST (ppm) 3.5	
POSSIBLE SOURCE OF POLLUTION Algae			
6. COMMUNICATIONS			
DISTANCE TO CONSUMERS 10 MI	ROADS Good	RAILROADS None	BRIDGES None
7. SITE CONDITIONS (If municipal system, use Items 9 and 10)			
SECURITY OVERHEAD CONCEALMENT GOOD. SECURITY AGAINST GROUND ATTACK MUST BE PROVIDED.			
DRAINAGE Good			
BANKS (If surface source) Stable & sloping - about 3' high			
DISTRIBUTION FACILITIES (existing) None			
8. SKETCH OF AREA (Show road net and traffic circulation) (Use reverse side for additional sketches, if necessary)			
SEE REVERSE SIDE.			

DA Form 1712-R, 1 Jun 61

Edition of 1 May 56 is obsolete.

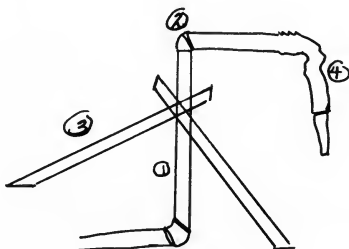
Figure 3. Reconnaissance report form for higher echelons—1st page.

9. SKETCH OF WATER POINT (Show proposed set up for immediate operation. If water point is a municipal system, include sketch of system) (Use reverse side for additional sketches, if necessary)



10. DESCRIPTION AND SKETCH OF PROPOSED DEVELOPMENTS (If municipal system, include survey) (Use reverse side for additional sketches, if necessary)

- ① PROPOSED TURNOUT (APPROX. 75 METERS LONG)  
② STANDPIPES FOR DISTRIBUTION



NOTE: SEE MATERIALS LISTED IN TEN 11.

Figure 4. Reconnaissance report form for higher echelons—2d page.

11. WORK ESTIMATES			
FOR IMMEDIATE OPERATION			
TASK	MAN-HOURS	EQUIPMENT	MATERIAL
① Construct Trench 1. Light clear- ing & grubbing 2. Haul & spread gra- vel.	96	① 5g Pioneer bet. ② D-7 (Dozer)	40 cubic yards of gravel
② Setup equipment.	6	1500GPH mobile water purifica- tion unit.	None
FOR DEVELOPMENTS			
TASK	MAN-HOURS	EQUIPMENT	MATERIAL
③ Sand- pipes	6	① Pipe wrenches ② Hammer ③ Saw	① 2" pipe - 1 pc. 8' long and 1 pc 2' long ② 2" 90° Elbow, 2 ea. ③ 2"x4" lumber 6' long - 2 ea ④ 1 length of 2" canvas hose with distribu- tion woggle. Note: Material for 1 ea sand- pipe.
TYPE OR PRINTED NAME AND GRADE		SIGNATURE	
Walter J. Newman, Jr		Walter J. Newman	

Page 3 (DA FORM 1712-R)

Figure 5. Reconnaissance report form for higher echelons—3d page.

## CHAPTER 3

# WATER SOURCES AND DEVELOPMENT OF WATER POINTS

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### Section I. DEVELOPMENT OF COMMON WATER SOURCES

#### 11. Basic Considerations

*a. Scope.* Development of a water source includes all work which increases the quantity and improves the quality of the water, or makes it more readily available for treatment and distribution. The development of surface water sources, springs, and sea water sources is considered in this section. The use of existing facilities is covered in chapter 7. For a detailed discussion of wells, see TM 5-297.

*b. Improvements.* In developing a source; dams, floats, galleries, and similar improvements may be used to increase the quantity and quality of the water. Some of the more common improvements are discussed in succeeding paragraphs.

*c. Precautions.* Elaborate developments should be avoided; simplicity brings more rapid results. A temporary water source should not be converted into a permanent one until the area has been reconnoitered for a source requiring less development. All intake hoses or pipes should be equipped with an intake strainer regardless of the clearness of the water source. Suction strainers should be protected from floating debris which may damage, clog, or unnecessarily pollute them. Proper anchorage of suction lines and strainers prevents loss of prime, punctured or kinked lines, and damage to strainer. Figures 6, 7, 11, and 15 depict several of the common methods of suction inlet anchorage.

*d. Intake Point.* Water at the intake point should be as clear and deep as possible. The strainer on the suction hose is placed at least 4 inches below the water level. This precaution reduces the possibility of the strainer becoming clogged with floating debris, or the prime being lost due to air getting into the suction line.

## 12. Inland Surface Water Sources

*a. Advantages.* For normal field water supply, surface water is the most accessible type of water source. This source also lends itself readily to the purification equipment common to most engineer units. Surface water is the most easily developed source of water. Various methods of constructing intake points for inland surface water sources are discussed in *b* through *g* below.

*b. Rocks and Stakes.* If the stream is not too swift and the water is sufficiently deep, an expedient intake may be prepared by placing the intake strainer on a rock. This will prevent clogging of the strainer by the streambed and provide enough water overhead to prevent the suction of air into the intake pipe. If the water source is a small stream or shallow lake the intake pipe can be secured to a post or pile as shown in figure 6.

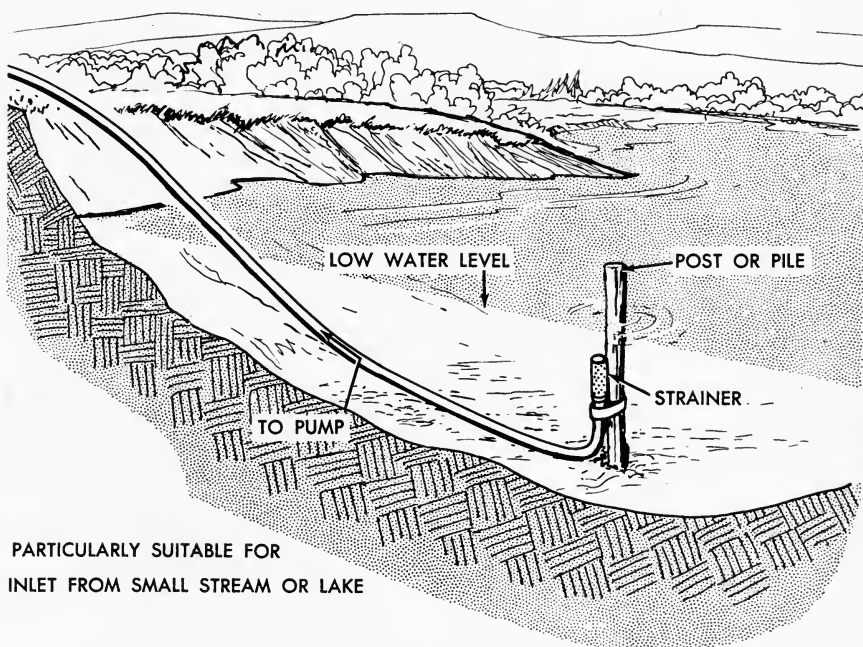
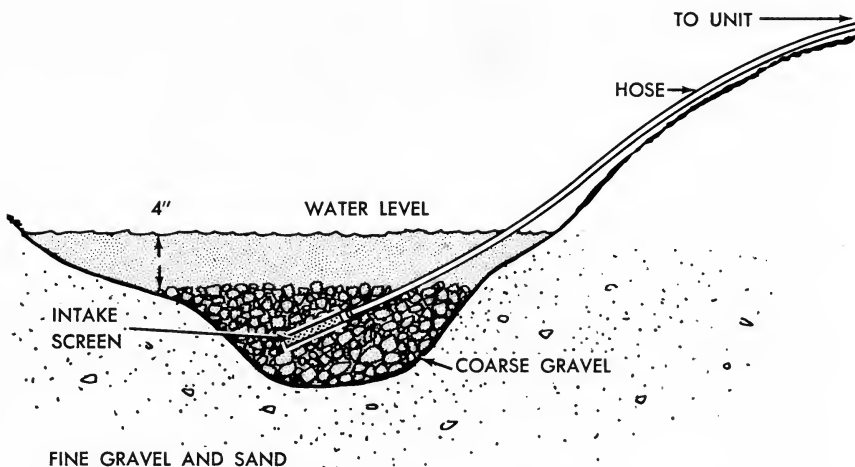


Figure 6. Direct intake, with hose on bottom of water source.

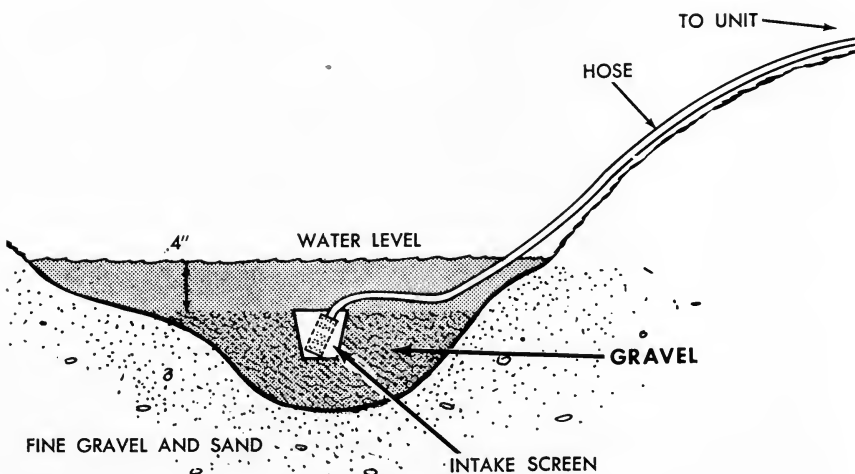
*c. Pits.* When a stream is so shallow that the intake screen is not covered by at least 4 inches of water, a pit should be dug and the screen laid on a rock or board placed at the bottom of the pit. Pits dug in streams with clay or silt bottoms should be lined with gravel to prevent dirt from entering the purification equipment (fig. 7). The screen is surrounded by gravel which prevents

collapse of the sides of the pit and also shields the screen from damage by large floating objects. The gravel also acts as a coarse strainer for the water. A similar method may be provided by enclosing the intake screen in a bucket as shown in figure 8.

*d. Dams.* The level of the water in small streams can be raised to cover the intake strainer by building a dam as shown in figure 9. In swiftly flowing streams, a wing or baffle dam can be con-



*Figure 7. Surface intake with hose buried in gravel-filled pit.*



*Figure 8. Use of bucket on end of surface intake.*



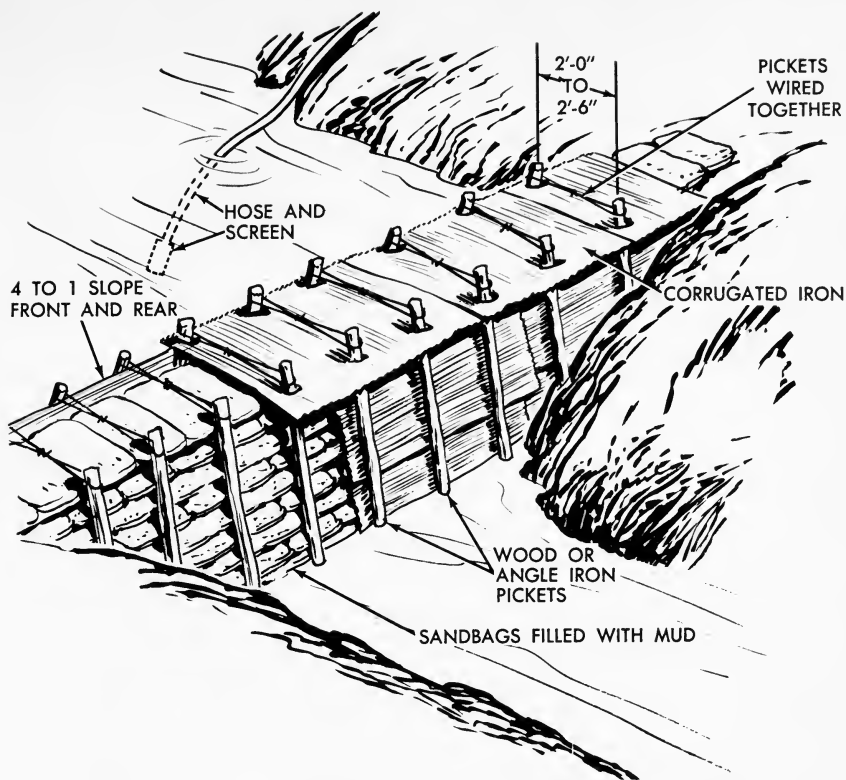


Figure 9. Improvised dam for impounding small streams.

structed to protect the intake screen without impounding the water (fig. 10).

*e. Floats.* Floats made of logs, lumber, sealed cans, or empty fuel drums can be used to support the intake strainer in deep water. They are especially useful in large streams where the quality of the water varies across its width or where the water is not deep enough near the banks to cover the intake strainer. The intake point can be covered by an adequate depth of water by anchoring or stationing the float at the deep part of the stream. The intake house should be secured to the top of the float, allowing enough slack for movement of the float. If support lines are used to secure the float to the banks, the position of the float can be altered to correspond to changes in depth by manipulation of the lines. The chief advantage of a float intake is the ease with which the screen can be adjusted vertically. Figures 11 and 15 illustrate two types of improvised floats.

*f. Galleries.* Water from muddy streams can be improved in quality by digging intake galleries along the bank. A trench is dug along the bank deep enough so that water from the stream



Figure 10. Baffle dam, for protecting inlet strainer.

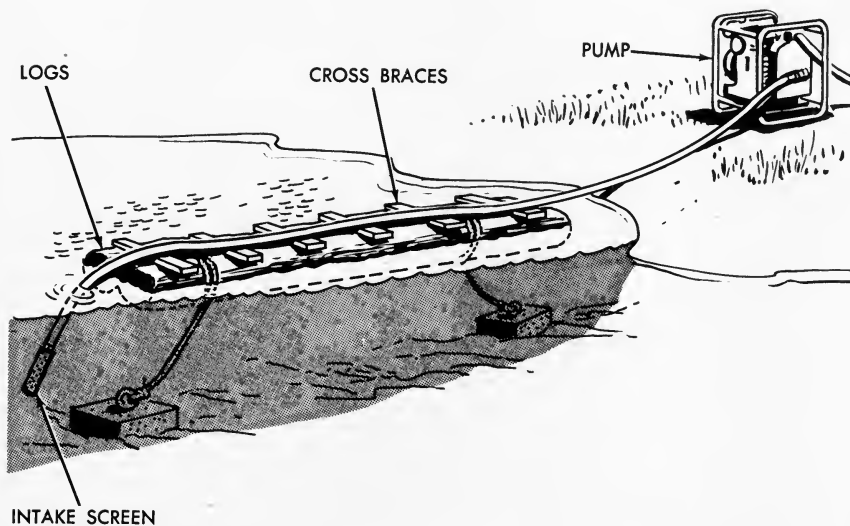
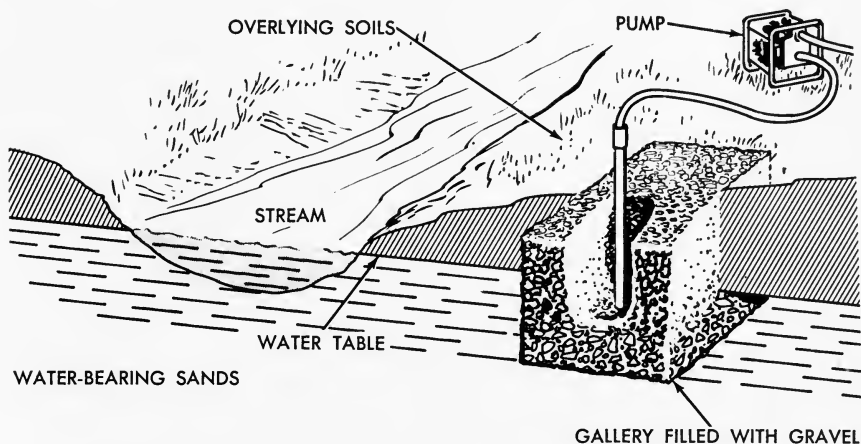


Figure 11. Float-type surface intake.

percolates into it so it intercepts ground water flowing toward the stream. The trench is filled with gravel to prevent the sides from collapsing. The intake strainer is placed in the gravel below the water line (fig. 12). The amount of work required to produce the gallery is justified by a reduction in the amount of chemicals needed to coagulate the water, the elimination of the necessity of frequently backwashing the filter, and the higher quality of water obtained.



*Figure 12. Gravel-filled gallery intake.*

*g. Drive Points.* Many times it is advantageous to utilize shallow ground water sources or percolated waters adjacent to a turbid surface water. Well points are issued in 2-inch diameter, 54-inch lengths. A drive cap is placed over the thread and the well point is driven into the ground with a sledge. Successive sections of pipe, each 5 feet long, are added and driven until the screen is well within the water bearing media. Several well points may be connected in parallel to supply sufficient water to the raw water pump. In developing drive point sources, it must be remembered that the pumps issued with field equipment have but 15 feet of practical suction lift. Pumping water from well points deeper than a maximum of 20 feet is mechanically impractical.

### 13. Springs

*a.* Springs yielding 20 gallons per minute or more of water can be used as a source of field water supply if properly developed. Springs may be developed by enlarging the outlet of the spring,

and by reducing loss by damming and conducting water to storage. To reduce possible pollution, springs should be cleared of all debris, undergrowth, top soil, loose rocks, and sand.

b. Water which flows from rocks under the force of gravity and collects in depressions can be collected in boxes or basins of wood, tile, or concrete. The collecting box should be large enough to impound most of the flow, and should be placed below the ground level so that only the top is slightly above the surface. The box should be covered tightly to prevent contamination and lessen evaporation. The inlet should be designed to exclude surface drainage and prevent pollution. This requires fencing off the area and providing proper drainage. Figure 13 shows a spring inlet which has been protected in this manner. The screen on the overflow pipe prevents the entrance of insects and small animals.

c. The flow of water from a spring located on a steep slope of loose earth can be obtained by the following two methods:

- (1) Constructing deep, narrow ditches leading from the spring to the point of collection.

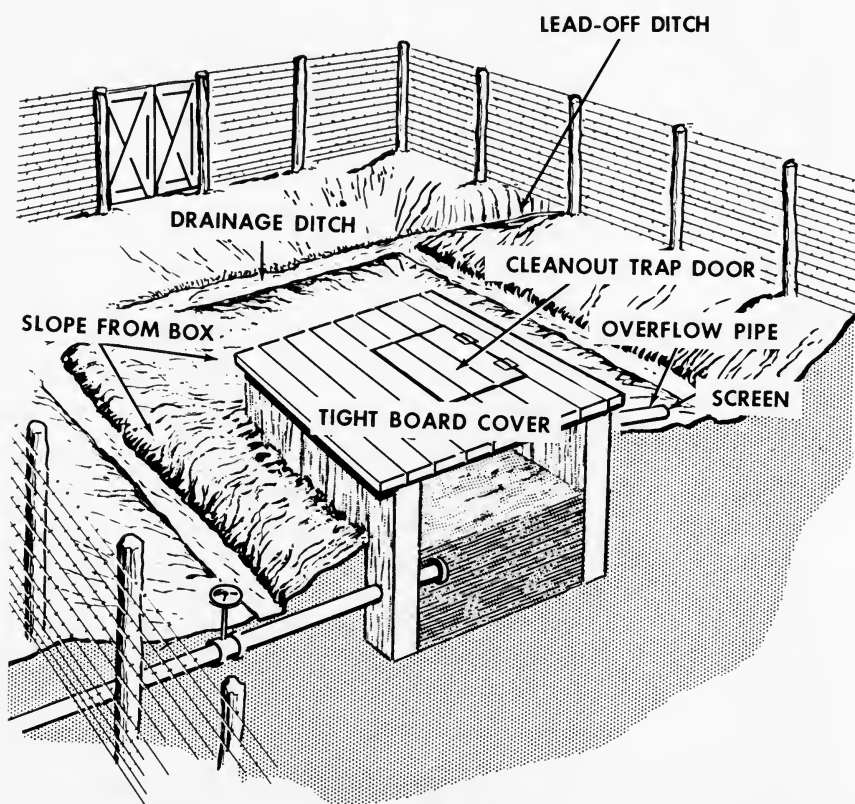


Figure 13. Spring inlet.

- (2) Constructing pipeline tunnels from the spring to the collecting point. Pipe of large diameter is more suitable for this purpose. The water from the tunnels can be trapped by constructing a dam at the point of collection.

d. Digging is a more positive and more economical method of developing a spring than blasting. The use of explosive in developing the yield from springs should proceed with great caution. Blasting in unconsolidated rocks may shift the sand or gravel in such a way as to divert the spring to a different point.

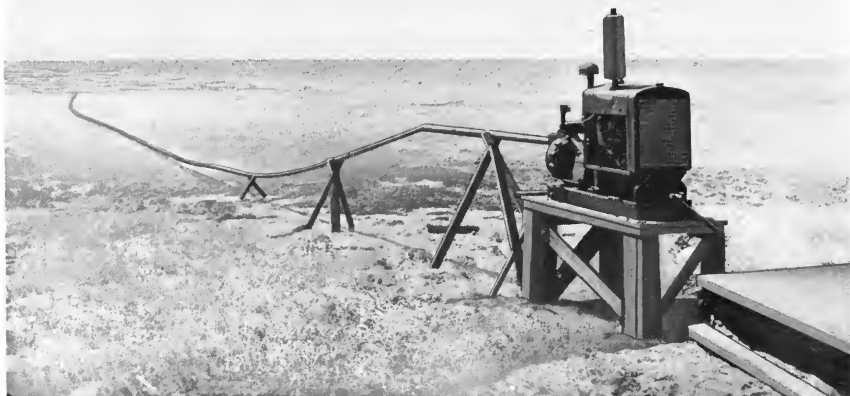
#### 14. Sea Water Sources

a. Sea water, as a source, is a type which is vastly different in its characteristics, as well as in the methods of purification, from other surface water sources. The chemical characteristics of sea water are such that normal coagulation and filtration are ineffective as treatment processes. The only economical process yet devised to successfully desalt and soften sea water is distillation. Distillation equipment is not normally found in engineer units, but may be requisitioned from engineer depots on a need basis. Relatively high cost and low quantity of distillate production are further limiting factors. Therefore, sea water should be used only when surface or ground sources are unavailable or inadequate to meet demands.

b. In developing sea water sources, consideration must be given to such factors as surf action, salt water corrosion, suspended sand and silt in the water, living organisms, surface oil along beaches, and the rise and fall of the water level with tide. Distillation equipment located on sheltered bays, harbors, lagoons, or estuaries can be supplied by intakes constructed in the same way as fresh-water surface intakes. On small islands where there is insufficient surface and ground water, and on or near open beaches, intakes for distillation equipment can be constructed as follows:

- (1) *Salt water wells.* Beach wells should, if possible, be used in preference to offshore intakes. Wells can be dug to tap fresh or salty ground water. This eliminates the problems caused by tides, surf, and shallow water close to shore. Such wells have an added advantage in that they can be constructed back of the shore line under natural overhead concealment. Driven and jetted wells may also be used effectively at beach locations.
- (2) *Offshore intakes.* Offshore intakes are sometimes required because of lack of time, men, or equipment or because of coral conditions which prohibit well construction. Intakes of either the rigid pipe or float type may be used but should be located in deep water beyond the

surf. They must be positioned vertically and be off the bottom but still beneath the water surface at low tide. In this way foreign materials in the water which might cause excessive wear on distillation equipment will be largely excluded. The rigid pipe type intake can be placed on timber supports as shown in figure 14 and anchored securely in position by piling or riprap. Floats securely anchored can support the intake screen in much the same manner as in surface waters (fig. 15). A rubber suction hose can be used to connect the rigid pipe on the sea bottom to the pipe supported beneath the float.



*Figure 14. Offshore salt water intake seen from shore end.*

## 15. Rain Water

a. In regions such as the tropical islands where there is abundant rainfall and rapid surface runoff, rain water is the primary source for the inhabitants. However, the quantity of water available may not be sufficient to supply the needs of both the civilian population and the military. Rain water as a source may be sufficient for small units for limited operations, but it should not be considered if other, more reliable sources are available.

b. The collecting surface may be constructed of tarpaulins supported by wood, metal, or concrete, and elevated so the water drains into tanks. After the water has been collected the tanks should be covered to safeguard the water from further contamination and pollution.

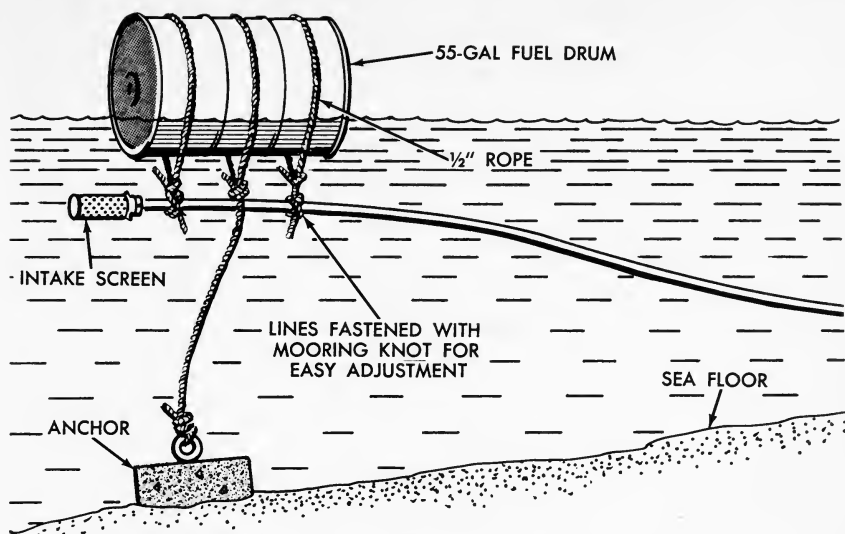


Figure 15. Float-type sea water intake.

## Section II. DEVELOPMENT OF ARCTIC WATER SOURCES

### 16. Characteristics

The selection and development of water sources in the arctic and subarctic require an understanding of conditions peculiar to the region. In the northern areas of Alaska, Canada, Greenland, and Siberia, temperatures remain below freezing during much of the year. Shallow surface water sources freeze to the bottom during the winter months. After the spring thaw, surface water collects in swamps, lakes, and streams. These sources can be developed for use during the summer season. Water from deep lakes and streams which do not freeze to the bottom can be developed for use throughout the year. If a satisfactory surface source cannot be located and developed, a ground water source should be developed. If no other satisfactory source is available, water may be obtained by melting snow and ice.

### 17. Summer Conditions

*a. Lakes and Streams.* During the summer months the numerous lakes and streams common to the arctic region may be developed as water supply sources. The intakes must be protected from floating objects, especially after the spring thaw. The streams in arctic areas often contain large amounts of silt which must be removed in the treatment process. The nonflowing sources contain less silt but require treatment to remove organic materials or other impurities.

*b. Muskeg Areas.* Muskeg areas can sometimes serve as water sources. Muskeg is a resilient soil covered with bog, and has a high water table. Muskeg water can be collected by building galleries or ditches intercepting the water table. This water generally contains a large amount of dissolved organic matter which must be removed in the treatment process.

## 18. Winter Conditions

During the winter months surface supplies freeze to the bottom unless the water sources are deep. Ice can develop to a thickness of 6 to 8 feet in a single winter season. Dams and reservoirs built to store surface water for use during winter seasons are seldom justified because of the danger of the water thawing the adjacent ground and causing slides, cave-ins, or settling. For this reason wells generally make more satisfactory water sources in arctic areas.

## 19. Snow and Ice

*a.* In northern arctic areas where deep wells cannot be sunk through the thick layers of permafrost, and the surface sources are frozen solid, water must be obtained by melting snow or ice. Ice is preferred to snow because it will yield more water for a given volume. Snow or ice may be contaminated. Therefore, all melt produced should be treated prior to drinking. Approximately 5 cubic feet of snow is required to yield 1 cubic foot of water. Several models of ice and snow melters are currently available for troop use.

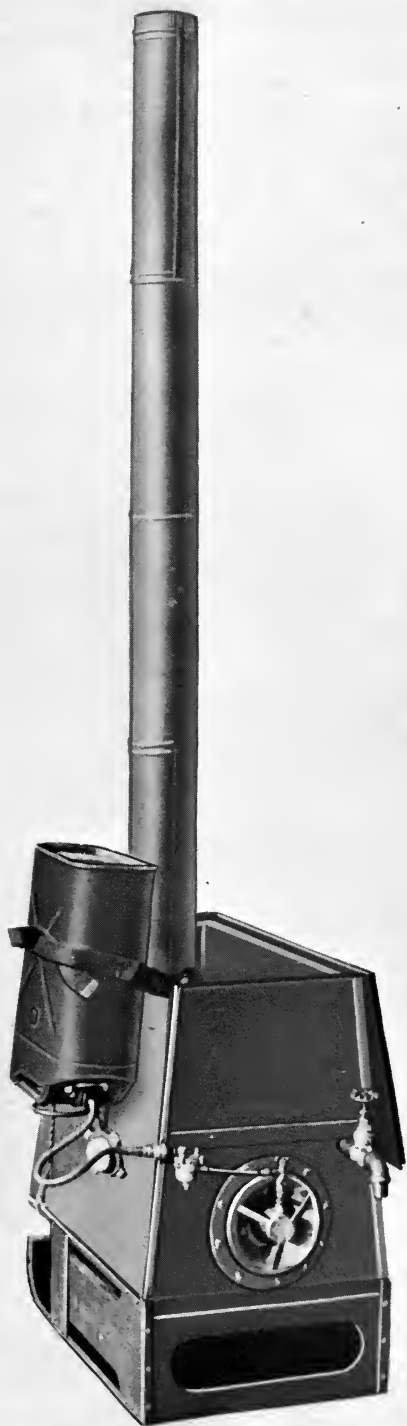
*b.* In emergencies, personnel can eat small quantities of snow. This snow should be placed in the mouth, rather than being sucked, to prevent chapped or cut lips. Only small quantities of snow should be consumed in this manner because consumption of large quantities will reduce the body temperature.

## 20. Methods of Preventing Freezing

With the exception of the 1,500 and 3,000 GPH van type, body-mounted water purification units, the Army has no standard water purification equipment which does not require special techniques of heating and insulating when used in below freezing weather. Methods of preventing freezing under arctic conditions follow.

*a. Treatment at Different Locations.* In many cases it is necessary for water treatment to proceed at different locations. For instance, when using a surface water source which is frozen over, a skid-mounted heated shelter may be constructed over the water hole to house raw water pumps and a settling tank. Raw water is pumped into the settling tank and drawn off into ski-mounted





*Figure 16. Melter, ice and snow, 25 gallons per hour.*

water tankers. These tankers then take the raw water to the permanent camp or installation where the water is filtered. Diatomite filters are maintained in heated buildings in these permanent camps, thus eliminating effects of cold weather on the equipment. After the water is filtered, it is chlorinated.

*b. Mobile Heated Shelters.* For highly mobile situations, an inclosed, heated truck body, or a heated wanigan mounted on a sled, can be used to advantage as a mobile water supply unit. This unit might include a small tank mounted over the stove which provides heat to the wanigan interior, so that the water is heated after it passes through the purification unit and before it is dispensed. Water supply tents or wanigans should be situated on the ice directly over the hole through which water is pumped, or as close thereto as possible, to reduce the possibility of water freezing in the intake hose.

*c. Draining Equipment.* The filters, hoses, pumps, and engines must be constantly checked for signs of freezing, and must be drained after using. Immersion type heaters may be used in the storage tanks or in the clear-well tanks to keep the water from freezing.

*d. Ice and Snow Melters.* Ice and snow melters (fig. 16) are batch type units in which ice or snow is manually loaded and



*Figure 17. Use of pumps to recirculate water in tanks.*

melted to produce water. The unit is portable, can be operated either indoors or outdoors, and can burn either gasoline or diesel fuel.

*e. Recirculation of Water in Tanks.* Pumps and engine sets available at water sites may be used to prevent freezing by recirculating the water in storage tanks (fig. 17). The number of pumps required and their location depends on the number of storage tanks used.

*f. Intake Points, Raw Water Pumps, and Hose.* Normally, water hoses may be laid directly on the snow as long as water in them is in circulation. When the water pumps are stopped, however, water in the hoses must be drained immediately if freezing is to be avoided. Freezing of the intake point is prevented by constructing a wooden box with insulating material for the cover as shown in figure 18. The raw water pump may be protected by covering with an insulated cover (fig. 17), or by constructing an insulated box (fig. 19). All water lines to or from pumping sets



*Figure 18. Raw water intake box.*



*Figure 19. Insulated box for raw water pump.*

should be suitably supported and pitched to facilitate rapid drainage when pumping stops.

*g. Water Storage and Distribution.*

- (1) Storage facilities are a necessary part of any water-supply system. They provide a reserve for peak loads and emergencies such as firefighting, and against breakdown of pumping equipment. Adequate provisions must be made to prevent freezing of the stored water. Small tanks or open basins should be inclosed in a heated building, while elevated or outdoor tanks must be properly insulated.
- (2) Water distribution systems, particularly buried pipelines, present special construction problems in permafrost regions. Therefore, special insulating and heating measures must be taken to prevent freezing of water in pipelines under arctic conditions. In small systems, freezing may be prevented by preheating, or heating the water at the source, to approximately 38° F.

## Section III. DESERT GROUND WATER

### 21. Types of Desert Regions

*a. Basin-and-Range.* Most desert regions throughout the world have a basin-and-range type of topography. Such regions consist of scattered mountain ranges, separated by basins which are filled with alluvial sediments. The rain that falls on the mountains flows into the basins and is absorbed by the sediments. Wells can be drilled to tap the ground water present in the sediments.

*b. Plateau.* Other desert regions, such as those in parts of northern Africa and interior Australia, occur on high plateaus, without mountain ranges. Such regions lack the deposits of alluvial sediments and receive very little rainfall. Supplies of ground water near the surface are rarely available. The only possible source of water is aquifers which transmit water from distant intake areas. If a geologic reconnaissance indicates the presence of such an aquifer, test drilling to tap it may be justified.

*c. Less-Known Areas.* In desert areas of Asia, Africa, and South America, where little geological information is available, there may be undeveloped water supplies at depths of several hundred feet. Attention to areal geology may indicate that test drilling to depths below those reached by native wells is justified.

### 22. Physiography of Basin-and-Range Regions

*a. Topography.* The basin-and-range topography typical of most desert regions is characterized by great waste-filled valleys, separating high mountain ranges. Many such valleys are interior basins, with no river outlets. Streams running down the mountains lay coarse, fan-shaped alluvial deposits along the sides of the mountains and into the valleys. Most of the downflowing water sinks and disappears into these deposits. In most such valleys, a permanent zone of saturation may be found in the lower part of the valley fill. This water can be tapped by wells. The water from the upper slopes that does not sink into the deposits or is not lost by evaporation is carried by interior drainage into the lowest parts of the closed desert basins, where it collects. This water is discharged to the atmosphere by evaporation, leaving salt concentrations near the surface. In locating a water supply of good quality in a basin-and-range desert region, the main problem is to avoid the common salty water.

*b. Playa Lakes.* "Playas" or "playa lakes" are the barren clay flats resulting from the muddy accumulations which collect in the low basins and become dry after losing water by evaporation or seepage. The playas are smooth and flat, and have a lake-basin type topography. The water held in the subsurface sediments

keeps the surface of some playas moist. Others, where subsurface water escapes downward through openings in bedrock below the sediments, are dry except after rains. Salt water generally occurs near the surface in most playas, but fresh water may underlie it.

### 23. Ground Water Occurrence

The typical desert basin can be divided into three principal parts according to ground water occurrence: the mountain range, which contributes most of the runoff, but has little ground water; the upper alluvial slopes, consisting of coarse debris and containing ground water at considerable depths; and the valley fill in the lower parts of the basin, which contains most of the ground water. The water in the central part of the basin is often salty. The quality of water obtained in the mountains is good but quantities are generally very small. The fresh water in the alluvial slopes may be obtained by placing wells to depths as great as several hundred feet. Test drilling is necessary in unexplored basins because the thickness and character of deposits vary from place to place.

### 24. Vegetation as Indicator of Ground Water

Plants are extremely valuable as water indicators in desert regions. Experience has shown that the various species of ground water plants not only indicate the presence of water but also its quality and approximate depth below the surface. Some species of plants reach water at or near the water table but most plants get their water from the soil moisture above the water table. In arid regions the presence of plants that tap the water table indicates that ground water is close to the surface. In more humid regions the greater abundance of water in the soil reduces the value of plants as indicators of a high water table. Ground water plants sometimes obtain water from a perched water table in which case the available water supply may be limited. Ground water plants generally occur in a zone around the central playa of a basin but not in the center itself because of the alkaline clays at the surface. Generally, plants other than cacti, sagebrush, and the yuccas will not grow unless there is a subterranean water table within 25 feet of the surface.

## Section IV. DEVELOPMENT OF WATER POINTS

### 25. Purpose

a. The development of a water point is the gradual improvement of the water point to increase the quality and quantity of the water, and the efficiency of its water-treatment and distribu-

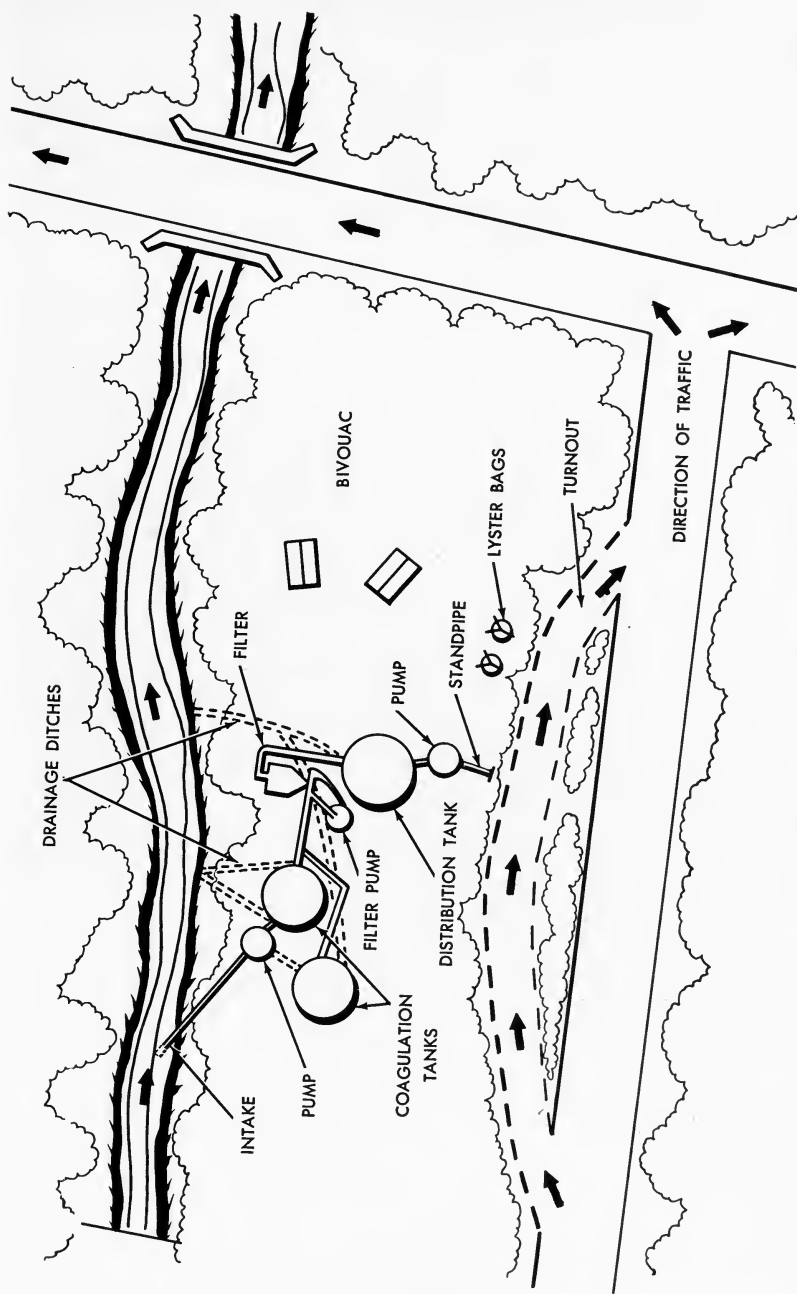


Figure 20. Development of typical combat water point.

tion facilities. Orderly development serves to eliminate those bottlenecks and other shortcomings which may occur following the establishment of a water point. Figure 20 shows the layout of a typical water point.

b. All work done during water point development should be directed toward six objectives. Unless the work furthers one or more of these objectives, it is unnecessary and should not be done. The work must—

- (1) Increase the quantity of potable water available.
- (2) Improve the quality of water produced.
- (3) Lessen distribution problems.
- (4) Decrease maintenance.
- (5) Improve security.
- (6) Improve living conditions of water point personnel.

## **26. Planning**

Proper planning is essential to the orderly development of a water point and should be foremost in the minds of reconnaissance and supervisory personnel. Whenever possible, a site requiring the minimum improvements should be selected. In planning improvements, removal of bottlenecks that limit operations should be given priority over problems of lesser importance. A schedule of recommended improvements should be prepared and followed. Supervisory personnel at each site should be well trained in water point development and have an appreciation for its results. (See app. IV for a checklist for water point development.)

## **27. Order and Extent of Development**

a. The relative importance of the problems encountered at each site and the tactical situation will determine the order in which improvements are to be made at a water point. For example, in jungle terrain where water is readily available and cover and concealment good, but roads are poor and snipers are present, distribution facilities and security are considered first. Priority should be given to those conditions which are necessary to establishing the water point and providing troops with water.

b. The extent to which a water point is developed depends primarily on the time, labor, troops, and materials available to do the work. At frontline installations, development is held to the minimum consistent with supplying enough potable water to the troops. However, in rear areas the extent of development varies with the size of the water point, the problems to be overcome, and the permanency of the installation.

## **28. Drainage**

The importance of providing for adequate drainage in develop-



ment of a water point cannot be overemphasized. Waste water from filters, leakage from tanks, and spillage from distributing facilities cause the area of operation to be continually wet. In addition to creating a sanitation problem, poor drainage may cause the area to be so muddy that it becomes inoperable (fig. 21). If vehicles cannot get to the point of distribution, the water point no longer serves its intended purpose. Such conditions can be eliminated by providing adequate drainage at each site.



*Figure 21. Effects of poor drainage, World War II water point.*

## 29. Supports and Platforms

*a. Low Platforms.* At forward water points, storage tanks should be erected on platforms resting on the ground (fig. 22). These platforms keep the tanks out of the mud, allow circulation of air underneath, and, as a result, prevent the tanks from rotting. They also eliminate the possibility of the tanks being punctured by rocks or other sharp objects. If the platform is prefabricated it should be so constructed as to allow for disassembly and transportation in the same truck with the purification equipment. On the other hand, if it is constructed in the field and dimensioned lumber is not available, saplings or native timbers can be used as a field expedient.

*b. Elevated Platforms.* If potable-water storage tanks are erected on elevated platforms, distribution can be improved by



*Figure 22. Ground platform for 3,000-gallon tank.*

using gravity feed to standpipes and distributing nozzles. However, such platforms are more suitable for rear areas or permanent installations than for forward areas. If dimensioned lumber is unavailable, tanks can be elevated by constructing a log-crib support. Expedient supports can be constructed from empty fuel drums.

*c. Operating Platforms.* Operating efficiency at poorly drained water points is increased by installing platforms to keep personnel out of the mud. These platforms may be duckboards or corduroy mats. The equipment platforms can be extended and joined to form operating platforms.

*d. Miscellaneous Supports.* In many cases expedients will be required because of tactical or local conditions. The use of field expedients is limited only by the ingenuity of personnel concerned. Some examples are (1) the use of a Bailey bridge to support water purification equipment over a stream subject to flash floods, and (2) a floating raft used to support distillation equipment.

### **30. Storage Facilities**

Storage facilities large enough to meet daily peak demands will increase efficiency by eliminating long waits at the water point by consumers. In addition to the tanks issued with the purification equipment, wood storage tanks and bolted steel tanks, as well as the standard fabric tanks, are available through engi-

neer depots as class IV supplies. Existing facilities may be used if available. Additional storage facilities must sometimes be improvised. Figure 23 shows an expedient made by lining an excavation with a tarpaulin. Soil from the excavation should be piled around the sides to prevent pollution by surface water. An additional tarpaulin should be placed over the excavation to serve as a protective cover for the water in the excavation (fig. 23). This tarpaulin should be large enough to extend beyond the edges of the excavation, so the water area is completely covered.

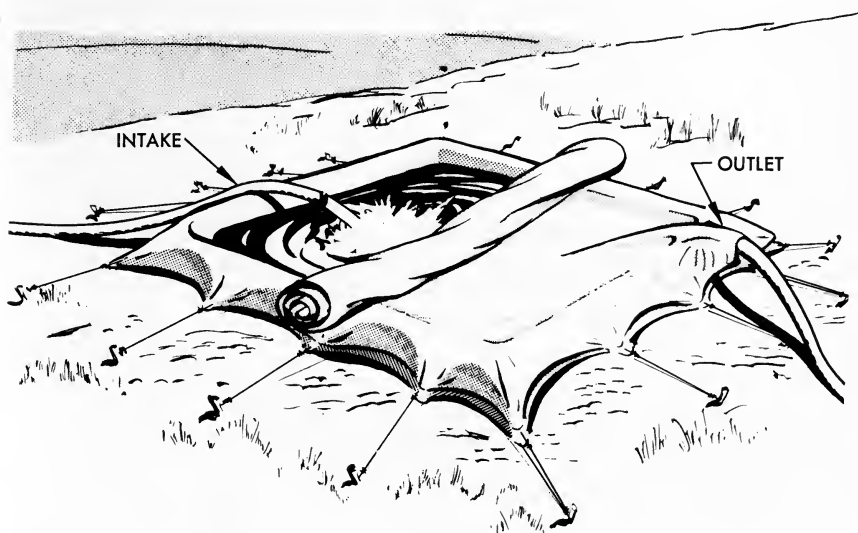


Figure 23. Expedient storage basin—tarpaulin.

### 31. Traffic Considerations

*a. Turnouts and Turnarounds.* When water points are located along traveled roads, facilities must be provided for loading consumers' trucks without interfering with normal traffic. A turnout is satisfactory for small installations. A turnout may be a widened section of the main road or a new one-way road past the water point as shown in figure 20, depending on labor and equipment available. For large installations, a turnaround is more convenient and efficient in that space is provided for the simultaneous distribution of water to more than one truck (fig. 24). Here, again, drainage is very important, especially if new construction is required for the turnouts or turnarounds.

*b. Traffic Signs.* The route to the water point should be adequately marked by signs posted by water supply personnel (figs.

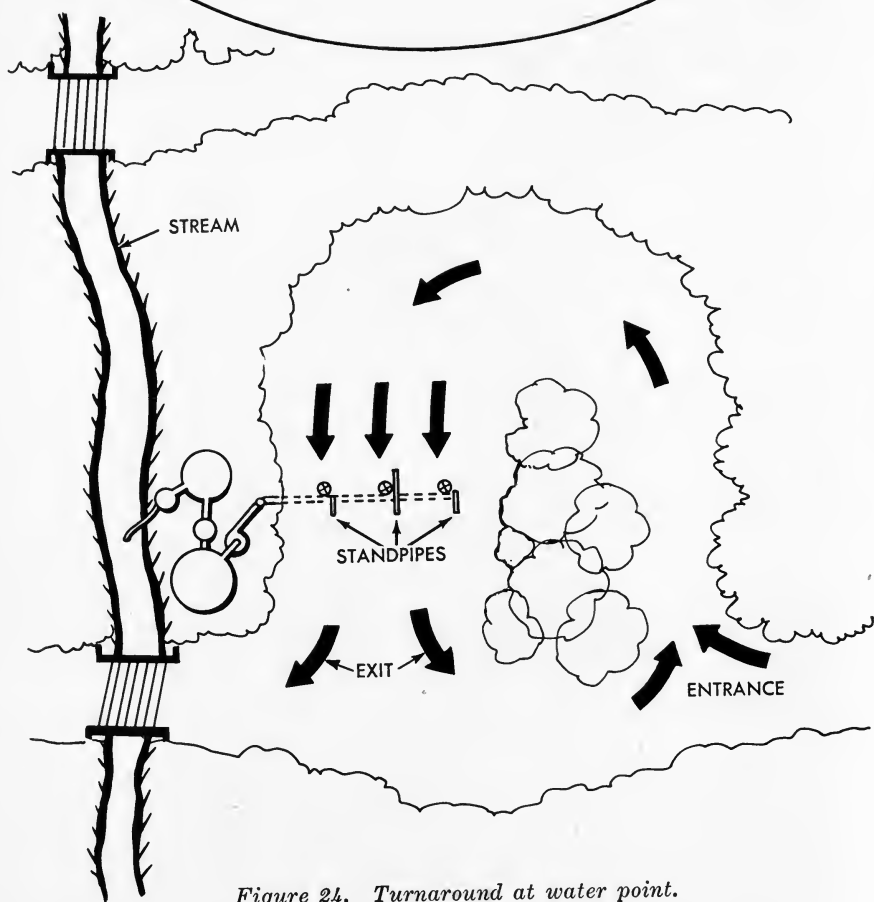
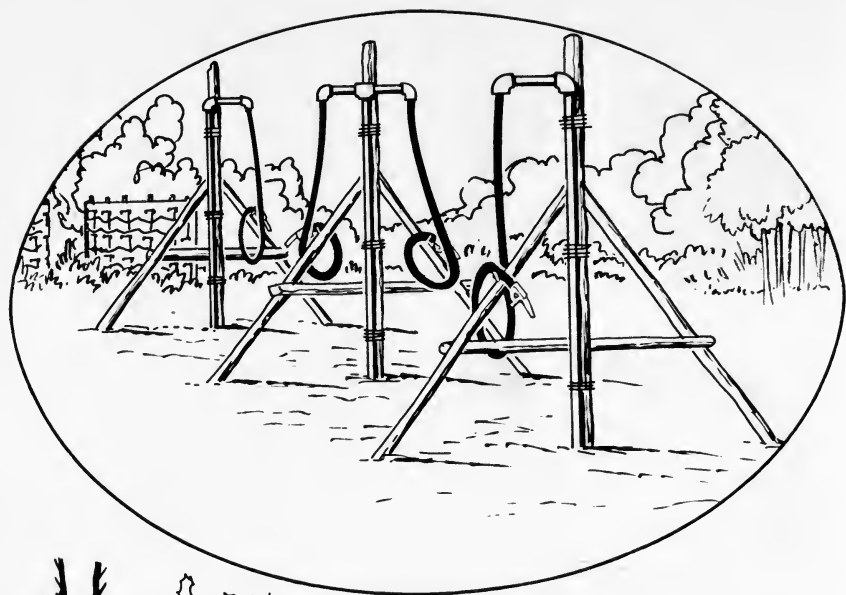
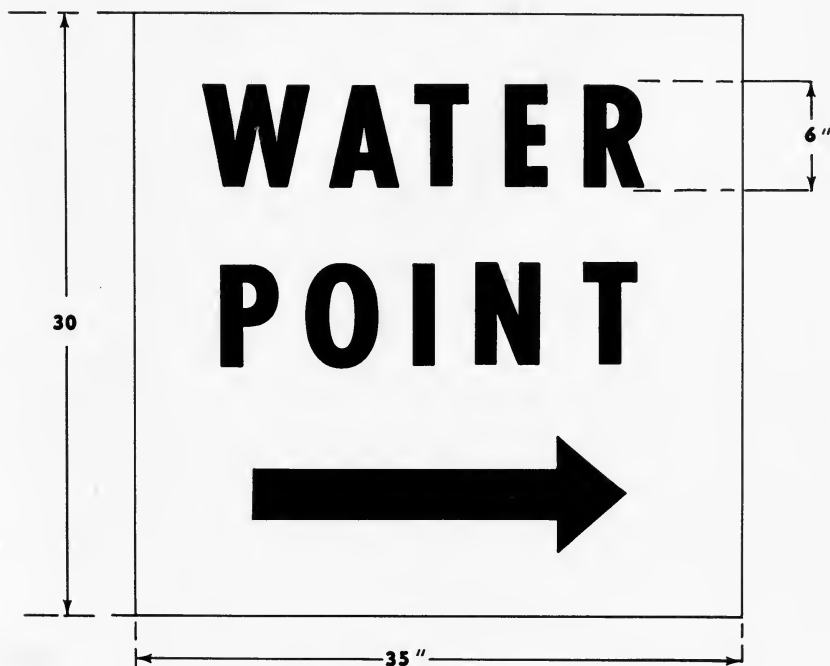
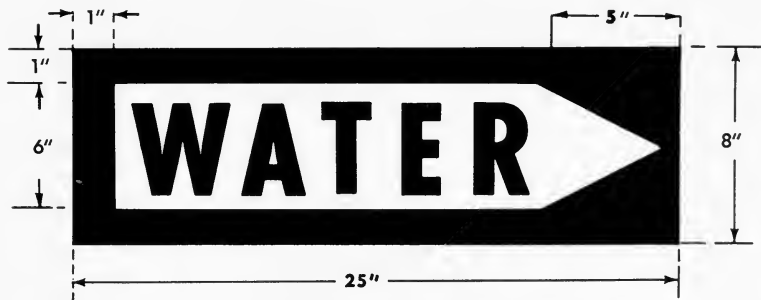


Figure 24. Turnaround at water point.

25 and 26). The signs should be so posted that they are clearly visible to vehicle drivers and so placed that crosstraffic interference will be kept to a minimum. They should be posted at all critical points such as side roads, crossroads, and forks within a 2-mile radius of the water point. Luminous buttons may be placed on the signs to help direct vehicles under blackout conditions. These signs should be prefabricated from metal and stored with the water purification equipment for field use.



*Figure 25. Traffic sign used for directing traffic.*



*Figure 26. Second traffic sign for water point.*

## 32. Standpipes

A water point standpipe is a rigid pipe which supplies water under pressure from an outlet high enough to service water trailers. The usual construction is a 2-inch pipe fastened to a vertical timber support as shown in figure 24. Several standpipes can be supplied from a common underground header. The most satisfactory outlet for standpipes is a short length of rubber suction hose with a safety nozzle. The safety nozzle should be suspended so it cannot touch the ground and become contaminated. In the absence of a safety nozzle for the hose, a valve may be inserted in the standpipe.

## 33. Camouflage

*a. Purpose.* Camouflage misleads the enemy by misrepresenting the true identity of an installation, an activity, or an item of equipment. See FM 5-20 for the basic principles of camouflage.

*b. Camouflage of Water Points.* The water source may or may not be in the immediate vicinity of friendly forces and, as a result, imposes a special problem of security. The best means of reducing the chances of attack is to deny the enemy any information concerning the location of the water point. This can be done by maximum use of overhead concealment and the use of camouflage nets to distort equipment outlines and shadows. Camouflage nets are particularly applicable for use with the mobile purification unit where overhead concealment is lacking. Whenever possible, parking areas, turnouts and turnarounds, and all distribution facilities should be provided with overhead concealment.

## 34. Bivouac Areas

*a. Selection.* In addition to the other steps involved in developing a water point, a bivouac area must be selected for water point personnel and security forces. In selecting a site, the factors of security, facilities, sanitation, and comfort of the troops should be considered. Although the situation may not permit selection of a site which fully meets all requirements, great emphasis should be placed on all comfort and health considerations so far as they do not interfere with the mission.

*b. Water Supply Personnel.* Within the limitations described in *c* below, water supply personnel should be conveniently located with respect to the water point. Such a location will facilitate the arrangement of "shifts" and make personnel readily available in case of emergency.

*c. Location.* The bivouac area should be located at least 100 feet away and downstream from the selected water source. See

FM 21-10 for field sanitation and other desirable features for campsites.

*d. Latrines.* Latrines should be located at least 100 yards away and downstream from the water source. Latrines should not be dug below the ground water level nor in place where the human waste may drain into and contaminate the water source.

### 35. Security

Since troop morale, welfare, and health depend greatly on a safe water supply, it is essential that commanders take measures to provide security for water points. A lack of security could result in complete loss of a water point or enable an enemy to contaminate potable water storage facilities and incapacitate all consumers for combat. The use of nuclear warfare poses a new threat and shelters should be established to give water supply personnel some protection against an attack by nuclear weapons. (See FM 5-15 for types of shelters and their use.)

## Section V. EQUIPMENT

### 36. Purpose

The primary purpose of all water purification equipment is to make water safe for human consumption by removing or killing harmful bacteria which may cause sickness or death. The equipment currently available for use by Army troops is of two types: (1) batch and (2) continuous flow.

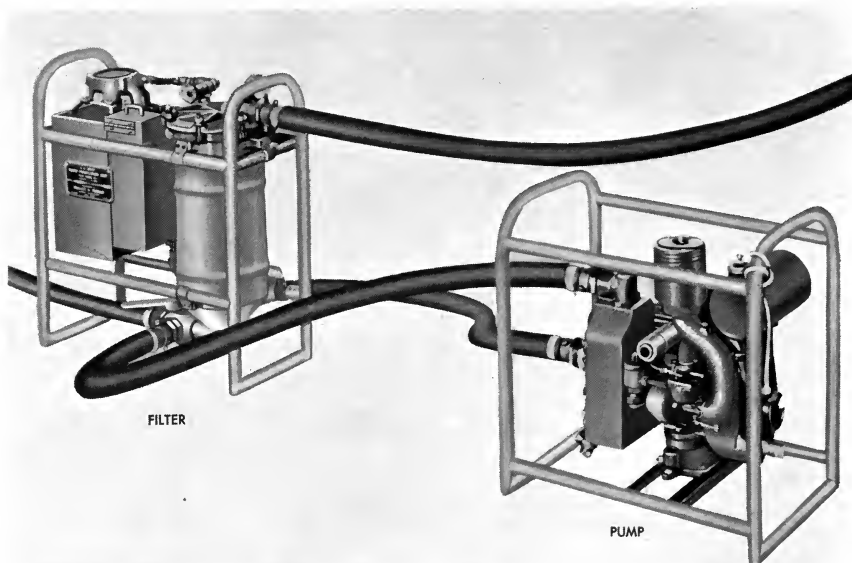
### 37. Batch Type Equipment

Batch type equipment is issued in three sets. These sets have a capacity of 15, 35, and 50 gpm (gallons per minute). The batch type equipment has been classified as STD-C equipment and is currently being replaced in the supply system by continuous flow type equipment. Details of operation and layout of batch type equipment may be found in TM 5-2101, TM 5-2103, and TM 5-2104.

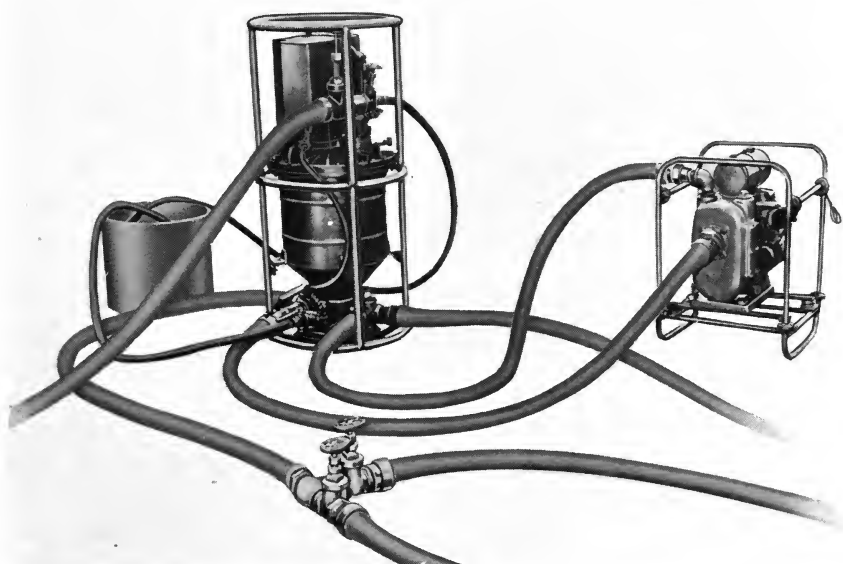
#### *a. Diatomite Water Purification Set No. 2, 15 Gpm.*

- (1) *Description.* The 15-gpm pack, diatomite, water purification equipment, Set No. 2, consists primarily of a pressure filter unit with a diatomite filteraid feed apparatus (fig. 27), four 500-gallon fabric tanks, two gasoline-engine-driven pumping sets, hose, a supply of coagulating chemicals, calcium hypochlorite, diatomite filteraid, two chemical feed baskets, a measuring cup, a hypochlorite scoop, and residual chlorine and pH testing equipment. Its average output is 15 gallons per minute.

- (2) *Transportation.* The set is portable and the entire unit and its auxiliary equipment can be carried in nine packs by men. The unit was designed primarily for use by isolated troops in the field who cannot be supplied with water by larger units.



*Figure 27. Diatomite water purification set No. 2, 15 gpm.*



*Figure 28. Diatomite water purification set No. 3, 35 gpm.*



*b. Diatomite Water Purification Set No. 3, 35 Gpm.*

- (1) *Description.* The 35-gpm portable, diatomite, water purification equipment, Set No. 3, consists primarily of a pressure filter unit with a diatomite filteraid feed apparatus and precoat tank, three 3,000-gallon fabric tanks, four gasoline-driven pumping sets, suction hose, a supply of coagulating chemicals, calcium hypochlorite, diatomite filteraid, two chemical feed baskets, a measuring container, and a chest containing discharge hose, fittings, and residual chlorine and pH testing equipment. Figure 28 shows the pressure filter unit with one pump and engine set in operating position. The average output of the filter unit is 35 gallons per minute.
- (2) *Transportation.* The set, complete with auxiliary equipment, is usually transported in a 2½-ton truck which tows a 1½-ton trailer. The equipment is loaded on both the truck and trailer.

*c. Diatomite Water Purification Set No. 4, 50 Gpm.* The 50-gpm portable, diatomite, water purification equipment, Set No. 4, is essentially the same as Set No. 3, with the following exceptions:

	<i>Set No. 3</i>	<i>Set No. 4</i>
Hoses, suction .....	1½ in.	2 in.
Tanks, fabric, 3,000 gal .....	3 ea	4 ea
Pumping sets .....	4 ea	5 ea
Average output .....	35 gpm	50 gpm

## **38. Water Purification Units**

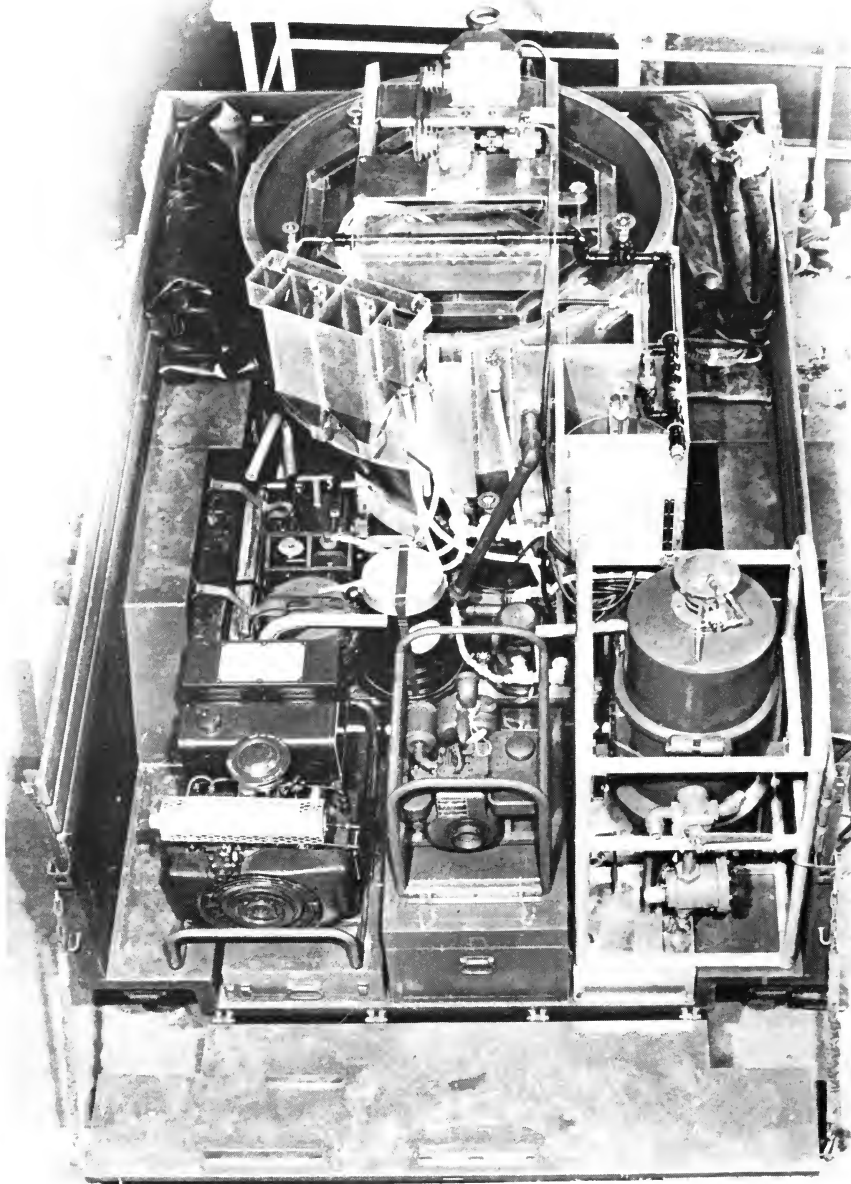
The continuous flow type water purification equipment was developed as a result of a need for a combat type mobile water purification unit which incorporates the necessary facilities and techniques for the treatment and purification of surface waters under all climatic conditions. The batch type water purification sets are not suitable for use in subfreezing temperatures without special techniques of heating and insulation. Continuous flow equipment is now standard and will replace batch type equipment in unit TOE's. Detailed instructions on operation and layout are given in TM 5-4610-202-10, TM 5-4610-203-10, and TM 5-4610-204-10.

*a. Water Purification Unit, Trailer Mounted, 600 Gph.*

- (1) *Description.* The 600-gph (gallon per hour) water purification unit and accessories are assembled in a special purpose cargo body, mounted on a 2½-ton, 2-wheel trailer chassis (fig. 29). The cargo body is specially designed to carry the 600 gph water purification unit and accessories. Major components consist of a coagulator assembly; filter section with one filter; a gasoline-engine-

driven 3 kilowatt generator; chemical feed equipment; raw water, filter, and distribution pumps; electrical control box; and necessary hose assemblies and chemicals. Two 500-gallon collapsible fabric tanks are provided for storage of filtered water.

- (2) *Use.* This unit was designed primarily for use by air-



*Figure 29. Water purification unit, trailer mounted, 600 gph.*

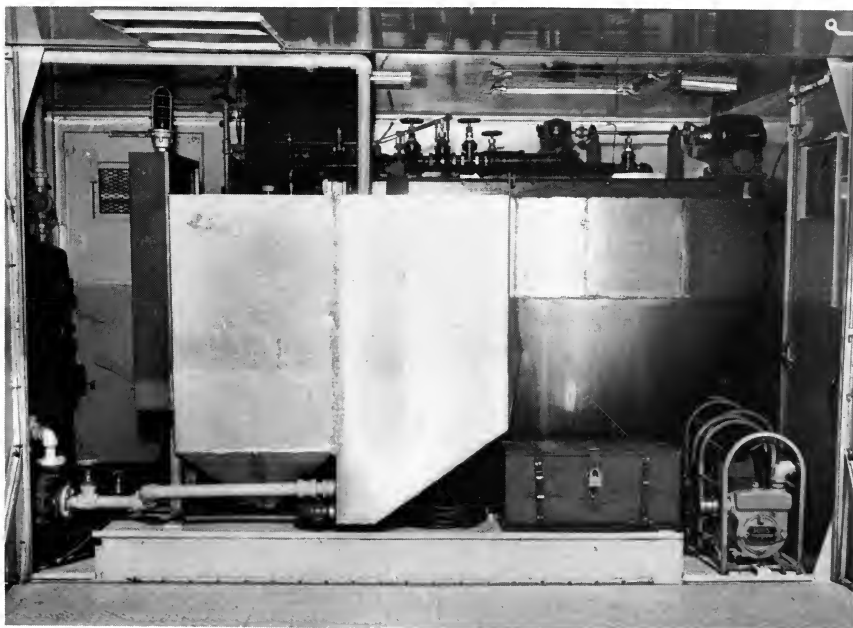
borne troops. The entire unit and accessories can be airdropped.

*b. Water Purification Unit, Van Type Body Mounted, 1,500 Gph.*

- (1) *Description.* The water purification unit, van type body mounted, 1,500 gph, consists of water purification equipment installed inside an insulated and heated van body (fig. 30). The heated van body contains the chemical feed equipment, the coagulator assembly, the filter section (one filter), the electrical control cabinet, and the necessary piping, valves, and control equipment. Supporting equipment furnished with the water purification unit includes a standard 2½-ton truck chassis on which the van body equipment is mounted; a 10-kw engine generator set, mounted on a standard towed type 1½-ton cargo trailer; two 1,500-gallon collapsible fabric water storage tanks; three portable centrifugal pumps, two electric driven and one gasoline engine driven; a 5-day supply of chemicals; and the necessary hose assemblies.
- (2) *Use.* The 1,500-gph water purification unit is issued to all engineer battalions.

*c. Water Purification Unit, Van Type Body Mounted, 3,000 Gph.*

- (1) *Description.* The water purification unit, van type body



*Figure 30. Water purification unit, van type body mounted, 1,500 gph.*

mounted, 3,000 gph, consists of water purification equipment installed inside an insulated and heated van body (fig. 31). The heated van body contains the chemical feed equipment; the coagulator assembly; the filter section (two filters); the electrical control cabinet; and the necessary piping, valves, and control equipment. Supporting equipment furnished with the water purification unit includes a standard 2½-ton truck chassis on which the equipment is mounted; a 10-kw engine generator set, mounted on a standard towed type 1½-ton cargo trailer; two 3,000-gallon collapsible fabric water storage tanks; three portable centrifugal pumps, two electric driven and one gasoline engine driven; a 5-day supply of chemicals; and the necessary hose assemblies.



*Figure 31. Water purification unit, van type body mounted, 3,000 gph, with pumps connected in series.*

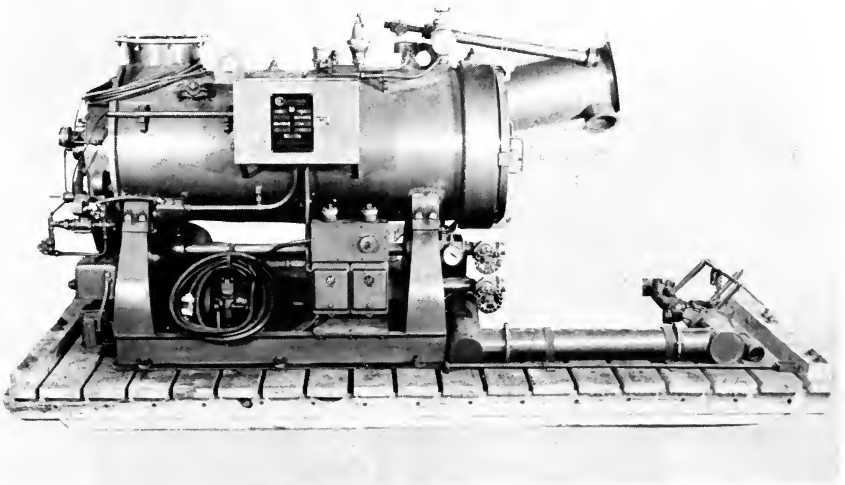
- (2) *Use.* The 3,000-gph water purification unit is issued to water supply companies and to water supply teams under TOE 5-500C. It may be obtained as a class IV item for units needing the larger capacity.

*d. Water Purification Unit, Base Mounted, 3,000 Gph.* The water purification unit, base mounted, 3,000 gph, is essentially the same unit as the 3,000-gph van type body mounted unit (fig. 32). The primary difference in the two units is the addition of



*Figure 32. Water purification unit, base mounted, 3,000 gph.*

an oil-fired water heater for use under arctic conditions (fig. 33). The unit is normally used as a permanent or semipermanent installation, and is issued as class IV equipment.



*Figure 33. Heater, water, oil fired.*

## Section VI. WATER DISTRIBUTION

### 39. Methods

Water distribution is the process of getting water from the water point to the place where it is to be used by the consumer. In forward areas this is normally done by use of water cans, tanks, trucks, or trailers. In rear areas, water distribution may include transportation of water by tanks, trucks, or trailers to a distribution point, where further distribution may be made by a system of pipes and pipelines. Some general considerations are--

*a.* A distribution schedule should be established giving the time of distribution for each unit and the water point to be used. This will eliminate the confusion and loss of time caused by a number of units reporting at a particular point at the same time.

*b.* New tanks, trailers, or other containers should be rinsed with a solution of 100-ppm (parts per million) calcium hypochlorite and water prior to initial use.

*c.* Water cans should be used for water only, and should be inspected periodically for rust and chips in the internal enamel.

*d.* Water trailers must be clean upon arrival at a water point. Cleanliness is a unit responsibility and water point supervisors should refuse to fill unclean containers. Unit commanders should inspect trailers for cleanliness, tightness of seals and seams, and maintenance.

*e.* Lead is an accumulative poison and should not be used in water storage, treatment, or distribution equipment (lead-lined tanks, pipes, etc.).

### 40. Trucks and Tank Cars

The TOE's of most units authorize a tank water trailer, 1½-ton, 2-wheel, 400-gallon capacity. This trailer is pulled to the field behind a 2½-ton truck and, under normal conditions, is sufficient to meet the demands of a company-size unit. In addition, water supply units may be assigned to a field army for additional support

### 41. Dry Points

Dry points are distribution points established for distributing treated water. Their use allows installation of treatment equipment at the best source even though it is some distance away from consuming units. Water is then trucked from the treatment point to the dry points where distribution facilities can be more conveniently located for consumers. A single water point can serve several dry points, especially when the bulk of the water goes to a few large users such as bakeries, hospitals, and encampments (fig. 34).

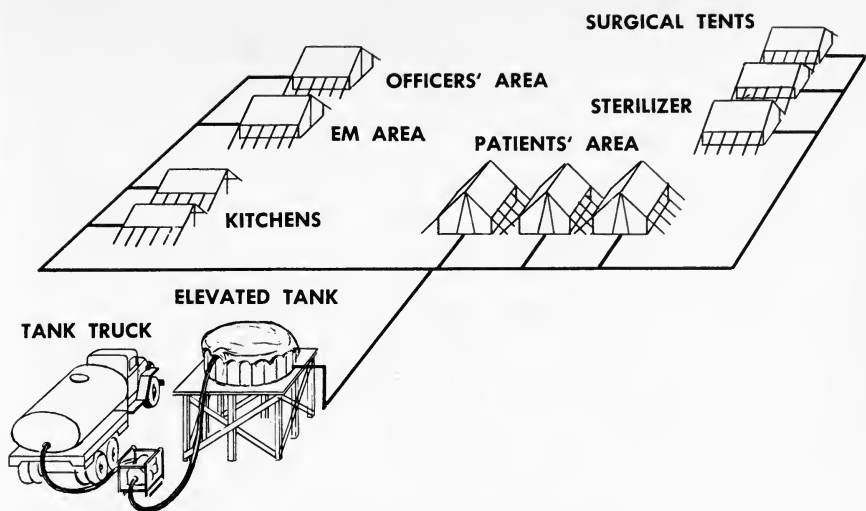


Figure 34. Dry point for a hospital in corps area.

## 42. Pipelines and Pumps

Pipelines may be used to carry water over terrain that is inaccessible to trucks. Pipelines offer fewer maintenance problems and a greater potential output than can normally be obtained by the use of tank trucks. However, pipelines are not generally used in the field because of cost, construction time, availability of equipment, and adaptability to field terrain. A complete pipeline installation includes a power-driven pump, rigid pipe and fittings, pipe supports to bridge depressions, and a receiving reservoir. The standard pumping sets furnished with purification units do not develop sufficient head for general pipeline use. The high head pumps and pipe for pipelines may be requisitioned for engineer depots or salvaged from damaged civilian installations. Refer to TM 5-350 for design-procedures.

## 43. Cleaning Emergency Water Containers

In cases of extreme emergency, gasoline cans, drums, and tanks may be safely cleaned for conveying and storing potable water by steaming or by proper use of detergents. After cleaning, the containers should be disinfected with chlorine solution. Containers used for hauling such liquids as apple juice, vinegar, wine, methylene chloride, yeast, sugar, corn syrup, varnish, and various oils also may be properly cleaned.

*a. Gasoline Containers.* Recommended procedures for cleaning leaded and unleaded gasolines from containers to be used for transporting water are given below:

(1) *5-gallon cans.*

- (a) Use only newer cans with bright interiors.
- (b) Drain the can thoroughly (10 to 15 minutes).
- (c) Fill the can one-half full with water, add 1 ounce of powdered soap or 3 ounces of powdered activated carbon, and shake for 5 minutes.
- (d) Rinse thoroughly several times; the last time fill to overflowing and discard the water.

(2) *50-gallon drums.*

- (a) Use only drums with bright interiors.
- (b) Steam for 1 hour or aerate for 15 minutes with compressed air; then add 10 to 20 gallons of water and 1 pound of powdered soap. Roll the drum for 15 minutes and discard the contents.
- (c) Add 10 to 20 gallons of water and  $\frac{1}{2}$  pound of activated powdered carbon. Again roll the drum for 15 minutes and discard the contents.
- (d) Rinse repeatedly if time and supply of water permit; fill the drum to overflowing and discard the contents.
- (e) Limit storage of water in drums to 1 week; if odors occur, add 1 pound of powdered activated carbon and shake for 15 minutes.

(3) *Tank trucks.*

- (a) Drain completely.
- (b) Steam for 90 minutes.
- (c) Flush with pressure hose.
- (d) Fill to overflowing.
- (e) Drain to gage level.
- (f) If no color or sediment is evident, water transported in tank trucks may be used up to 18 hours after filling.
- (g) Flush the tank after each refilling.

(4) *Tank cars.*

- (a) Steam at least 6 hours.
- (b) If possible, have interior thoroughly flushed by pressure hose.
- (c) Fill to overflowing and drain.

(5) *Alternate cleaning method.* Where steam is not available, a detergent may be used for removing gasoline. Commercial detergents containing polyphosphates are effective cleaning agents in both hot and cold water.

*b. Other Liquid Containers.* Tanks and containers used to transport juices, oils, and other liquids may be cleaned as follows:

- (1) Open the drain and flush with hot water.
- (2) Steam with an emulsifying detergent until the tank is clean. Where steam is not available, circulate the detergent at a temperature of 180° to 210° F., changing



the location of the nozzle to keep the interior continuously wet from top to bottom. Return the solution to the supply tank and recirculate until clean.

(3) Rinse the tank thoroughly with hot water and drain.

*c. Safety Precautions.* Tanks large enough to accommodate a man should never be entered without equipment to test for harmful or explosive gasoline vapors, unless the following precautions are observed:

- (1) An air line mask and air line hose with constantly supplied fresh air should be used.
- (2) Fire or explosion should be guarded against by using sparkproof equipment only and wearing composition soled shoes free of nails. These precautions must be observed by workers both inside and outside the tank.
- (3) The worker should use a safety belt to which a safety line is attached before entering the tank. While in the tank he must be kept constantly under the observation of two other workers who hold the safety line in their hands at all times. They should remove him from the tank at the first sign that he is being affected by the vapors. Artificial respiration should be administered if necessary.

## Section VII. WATER SUPPLY RECORDS

### 44. Report Forms

*a.* Three types of water supply records are kept: daily reports, inspection reports, and headquarters summaries. DA Forms 1713-R through 1717-R (figs. 35-40) are used to maintain these records.

*b.* These forms are authorized for local reproduction on 8- by 10½-inch paper. Each reproduction will include the form number, the form title, and the date of the form. The forms illustrated are designed to provide the minimum amount of information that will satisfy the following objectives:

- (1) Coordinate the operation of widely separated water points.
- (2) Safeguard water quality.
- (3) Improve efficiency of water treatment and distribution.
- (4) Decrease equipment maintenance.
- (5) Prevent unequal distribution of treated water.
- (6) Furnish supply data for higher headquarters.

### 45. Water Point Reports

Water points submit daily reports on their production and dis-

DAILY WATER PRODUCTION LOG (TM 5-700)								SET NO. 14	
Point No.		NCO in charge			Date				
2		SP4 Smith			21 Jun 60				

Time	No. of Tanks Coagulated	pH		Cl <sub>2</sub> Residual (ppm)	Alum (lbs)	Soda Ash (lbs)	Cl <sub>2</sub> (oz)	Activated carbon (oz)	Diatomite (lbs)
		Source	Filtered						
0800	3	7.2	7.8	2.5	15	8	9	—	—
0830	—	7.2	7.8	2.5	—	—	—	—	1 1/4
0900	1	7.2	7.6	2.1	5	3	3	—	1 1/4
0930	—	7.2	7.6	2.8	—	—	—	—	1 1/4
1000	1	7.1	7.8	2.5	3 1/2	1	3	—	1 1/4
1030	—	7.1	7.8	2.5	—	—	—	—	1 1/4
1100	—	7.1	7.8	2.5	—	—	—	—	—
1130	—	7.2	7.8	3.00	—	—	—	—	1 1/4
1200	1	7.2	7.8	3.0	3 1/2	1	3	—	1 1/4
1230	1	7.0	7.8	3.0	3	1 1/2	3 1/2	3	1 1/4
1300	—	7.0	7.8	2.5	—	—	—	—	1 1/4
1330	1	7.0	7.8	2.5	3	1 1/2	3 1/2	3	2 1/2
1400	—	7.0	7.8	2.5	—	—	—	—	1 1/4
1430	—	7.0	7.8	2.5	—	—	—	—	1 1/4
1500	—	7.0	7.8	2.5	—	—	—	—	—
1530	—	7.0	7.8	2.4	—	—	1	—	1 1/4
1600	1	7.1	7.8	3.0	3	1 1/2	4	3	1 1/4
1630	—	7.1	7.8	3.0	—	—	—	—	—
1700	—	7.1	7.8	3.0	—	—	—	—	1 1/4
1730	—	7.1	7.8	3.0	—	—	—	—	1 1/4
Chemicals used					36	17 1/2	30	9	21 1/4
Chemicals on hand					114	82 1/2	114	49 1/2	230
POL used	Gasoline (gal)	12		POL on hand	Gasoline (gal)	118 +			
	Oil (qt)	2			Oil (qt)	18			
	Grease (lb)	1/2			Grease (lb)	2 1/2			

REMARKS:

Figure 35. DA Form 1713-R (Daily Water Production Log) (front of form).

DAILY WATER PRODUCTION LOG (CONTINUOUS FLOW EQUIPMENT)  
(TM 5-700)

Point No. 3 (1500)

NCO in charge  
SP4 JONES

Date 10 Jul 60

[illegible]

REMARKS:

Figure 36. DA Form 1713-R (Daily Water Production Log) (back of form).

DAILY WATER DISTRIBUTION LOG  
(TM 5-700)

Point No.	NCO in charge	Date
2	Sgt Smith	8 Jun 60

TIME	AMOUNT GALLONS	PICKED UP BY (USING UNIT)
0810	350	414 MAN ORD Rwp
0817	350	55 MP Co DMZ
0825	350	515 Engr Bn (C) "B" Co Pet
0900	350	515 Engr Bn (C) "A" Co Hlt
0905	350	515 Engr Bn (C) "C" Co Rd.
1000	750	515 Engr Bn (C) Ely Co M.J.
1020	750	515 Engr Bm(C) HQ CO M.J.
1030	350	214 Q/M Whse Co LMM
1045	750	253 MASH DRC
1050	350	253 MASH DD
1055	350	515 Co
1115	75	
		TOTAL GALLONS 8000

REMARKS:

DA Form 1714-R, 1 Jun 61

Edition of 1 May 56 is obsolete.

Figure 37. DA Form 1714-R (Daily Water Distribution Log).

WATER POINT INSPECTION REPORT (TM 5-700)		DATE 10 Jun 60
TO: C.O. 515 Eng Bn (C)		FROM: (Organization) 76 Evac Hosp
WATER POINT INSPECTION	WATER POINT #3	INSPECTION RATING Excellent
NAME OF MAP COORDINATES SALINAS 07359216	DATE 9 Jun 60	INSPECTOR L. M. DOKES, Capt MSC
RESIDUAL CHLORINE		
Filter Outlet (ppm) 3.2	Distributing Nozzle (ppm) 2.8	
CONDITION OF		
1. WATER POINT (List defects and improvements of layout) Excellent		
2. EQUIPMENT (tanks, hose, nozzles, etc.) Excellent (One nozzle leaking slightly)		
3. ENGINES (List numbers of those needing repair) Excellent		
4. PERSONNEL (Note sanitation, personal equipment) EXCELLENT		
REMARKS  The men at water point # 3 should be commended for their initiative in production of water of very high quality		
TYPED OR PRINTED NAME AND GRADE L. M. DOKES, Capt MSC		SIGNATURE L. M. Dokes

DA Form 1715-R, 1 Jun 61

Edition of 1 May 56 is obsolete.

Figure 38. DA Form 1715-R (Water Point Inspection Report).

WATER POINT DAILY PRODUCTION SUMMARY (TM 5-700)								DATE		
TO: G-4 BSA Linc ATL 671						FROM: (Organization) S-4/8 ENGR (C) Rm				
WATER POINT	HOURS OPER- ATION	PRODUCTION (Gallons)	GASO- LINE (Gal- lons)	OIL (Qts)	CHEMICALS USED					
					FERRIC CHLORIDE	LIME- STONE	CALCIUM HYPO- CHLORITE	ACTIONATED CARBON	ALUM	SODA ASH
#1	20	60000	18	2	-	-	42 oz		43.5#	21 #
#2	20	51100	16	-	-	-	36 lb	2 #	46 #	20 #
#3	20	58000	19	3	-	-	40 oz	2 #	46.5#	18 #
#4	20	53000	17	1	-	-	40 lb		44 #	19 #
DAILY TOTALS	80	222,100	70	6			152 oz	4 lbs	174lb	78lbs
TYPED OR PRINTED NAME AND GRADE <i>John C. Cardigan, Capt., C.E.</i>						SIGNATURE <i>John C. Cardigan</i>				

Figure 39. DA Form 1716-R (Water Point Daily Production Summary).

[illegible]

Figure 40. DA Form 1717-R (Water Point Daily Distribution Summary).

tribution of water, using DA Forms 1713-R and 1714-R (figs. 35-37). Since these reports are the basis for all subsequent water supply records, they should be filled out carefully; any inaccuracies will be reflected in the record of higher headquarters.

*a. Daily Water Production Log.*

- (1) The daily water production log, DA Form 1713-R (figs. 35 and 36), is designed so the operator can record pertinent information.
- (2) The daily production may be obtained by multiplying the hours of unit operation by the average rate of production. The quantity of water wasted can be determined by subtracting the quantity of water distributed from the quantity produced daily.
- (3) Tests entries required are valuable as reminders to operators of the quality control tests. Singular reports of routine control tests are of limited value due to seasonal variations in the source. Data gathered from reports of routine control tests performed over a period of several weeks or months is often valuable in learning the characteristics of a given source.
- (4) Equipment inspection records are valuable maintenance aids because they indicate the dates when pumps and engines were last overhauled. A record of the supplies used aids in restocking the point and prevents wasteful practices by the operators.

*b. Daily Water Distribution Log.* DA Form 1714-R shown in figure 37 shows the quantity of water drawn by various units and the time it was drawn. Daily production figures are usually based on these data. The form may be modified for specific use.

## 46. Inspection Reports

*a. Inspections by Water Supply Officer.* The responsible officer or his representative should make daily inspections of each water point. DA Form 1715-R shown in figure 38 indicates the information that must be obtained in making a satisfactory field inspection. The times of inspection and order of visiting the various water points should be changed daily.

*b. Routine Sampling.* Bacteriological analysis of water at the water point and in distribution is provided by the Army Medical Service. The analysis is made with a newly developed field membrane filter kit which enables the sample collector to initiate testing at the time of collection and to provide an answer within a day. The test results are provided by the headquarters of the unit providing the water. The record of these tests is a guide to the potability of the water being produced and is valuable in determining the origin of any intestinal disease that might occur.



*c. Inspections by Sanitary Officer.* Water points are inspected at frequent intervals by unit sanitary or medical officers to safeguard the health of consuming troops. The chlorine content of the water, sanitation of the water point, and bacteria of the treated water are carefully checked during these inspections. The sanitary officer can notify the headquarters concerned to stop production at any water point distributing unsafe water.

## **47. Headquarters Summaries**

*a. Daily Production.* DA Form 1716-R (fig. 39) is used to summarize the daily production reports of water points and is forwarded to higher headquarters, to the maintenance section, and to the supply section.

*b. Daily Distribution.* DA Form 1717-R summarizing daily distribution reports is shown in figure 40. This summary should be studied to detect any unusual consumption of water by various units. A copy of this summary is usually requested by higher headquarters.

*c. Monthly or Quarterly Reports.* Monthly or quarterly activity reports compiled from daily summaries are required by higher headquarters.

## CHAPTER 4

### WATER QUALITY

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#### Section I. INTRODUCTION

#### 48. Hydrologic Cycle

a. The hydrologic cycle is the term used to describe the natural circulation of the water in, on, and above the earth. Water occurs in many forms as it moves through this cycle. Figure 41 is a simplified illustration showing the steps in the cycle.

b. The steps in the hydrologic cycle include evaporation, precipitation, transpiration, infiltration, and runoff. Water is evaporated from water surfaces, land surfaces, and by transpiration. It is then condensed to produce cloud formations, and returned to earth as rain, snow, sleet, or hail. A portion of the precipitation evaporates, some flows over the earth as runoff into lakes and streams, and the remainder goes into the soil and thence into underlying rock formations by seepage or infiltration. Eventually the water which has seeped through the earth will find its way to the surface through springs, or will flow through porous media until intercepted by streams, lakes, or the ocean.

c. The cycle does not always progress through a regular sequence; steps may be omitted or repeated at any point. For example, precipitation in hot climates may be almost wholly evaporated and returned to the atmosphere. In such an instance the steps of infiltration, transpiration, and runoff are omitted.

#### 49. Natural Water

Absolutely pure water is never found in nature. The impurities in water vary from dissolved gases and chemical compounds to suspended matter such as disease organisms and dirt. While some of these impurities can be seen by the naked eye, others cannot, but can be detected by taste or odor. Still others can be detected by laboratory test only.

#### 50. Water for Military Use

Water for military use must be free of disease-producing or-

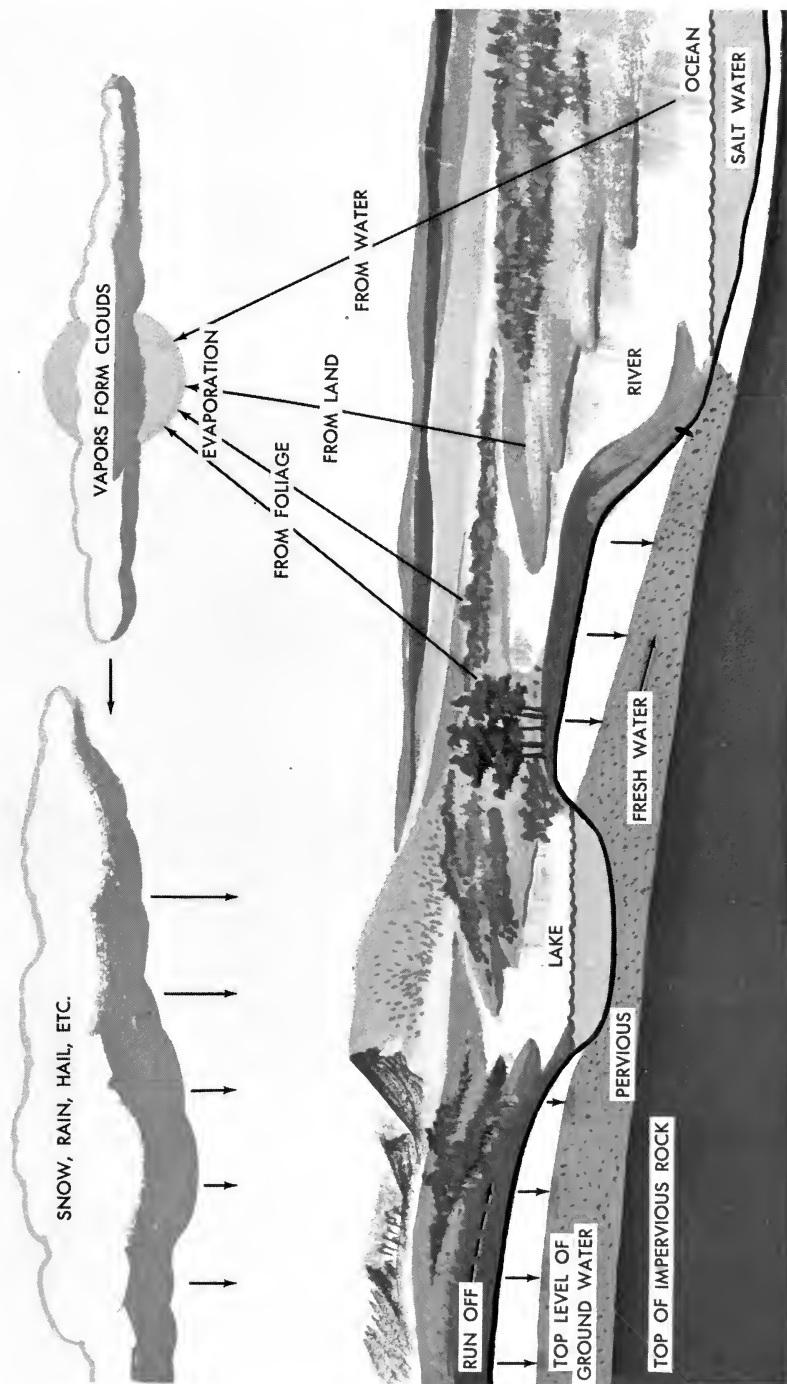


Figure 41. Hydrologic cycle.

ganisms, poisons, and excessive amounts of mineral or organic matter. Under these conditions the water is safe for drinking, cooking, and washing. In addition, when time and equipment permit, the water should be clear, cool, and free from objectionable taste and odors. Every effort should be made to provide troops with high quality water.

## 51. Contaminated, Polluted, Palatable, and Potable Water

*a. Contaminated water* contains potentially disease-producing organisms or poisonous substances which make it hazardous and, therefore, unfit for human consumption or domestic use. Water may be contaminated but not necessarily polluted.

*b. Polluted water* is water containing substances such as garbage, industrial waste, or mud, which make it objectionable because of appearance, taste, or odor. Polluted water is usually contaminated and may be easily detected.

*c. Palatability of water* is a term which describes the characteristic of being pleasing to the sense of taste. To be palatable, water should be significantly free from color, turbidity, taste, and odor, and should be cool and aerated. At least four human perceptions can be used in judging these qualities. They are the senses of sight (color and turbidity), taste, smell (odor), and touch (temperature). However, it must be understood that palatable water is not always safe to drink.

*d. Potable water* is water that is free from disease-producing organisms and organic and inorganic poisonous substances and, therefore, safe for human consumption. Although potable water is safe to drink it may not be palatable.

## 52. Classification of Naturally-Occurring Surface Water Supplies

For convenience, naturally-occurring surface water supplies may be divided into three primary categories: fresh water, brackish water, and salt or sea water.

*a. Fresh Water.* Fresh water includes flowing streams or rivers and water impounded by lakes or reservoirs. Most of the surface waters in the United States are fresh water. Army standards permit maximum chlorides of 250 ppm (parts per million), maximum sulfates of 250 ppm, and a maximum total dissolved solids of 500 ppm. The term "parts per million" is defined in paragraph 73a; maximum permissible concentrations of impurities are given in paragraph 61; and the formula for calculating total dissolved solids is explained in paragraph 89b.

*b. Brackish Water.* Brackish water is found in many regions throughout the world, but occurs most frequently as ground water in arid or semiarid climates. Brackish waters are highly mineral-

ized and contain dissolved solids in excess of 500 ppm, which make them objectionable as drinking water supplies. Total dissolved solids may be as high as 15,000 ppm. Both alkalinity and salinity range from very high to very low.

*c. Salt or Sea Water.* Water containing total dissolved solids above 15,000 ppm may be designated as salt or sea water. This is an approximation, since no clear-cut line of distinction can be drawn between brackish and salt water. Typical salt water has a very high sodium chloride content and a low alkalinity. It is generally found only in a free body of water such as ocean, sea, or estuary. The most abundant source, the oceans, may contain total dissolved solids up to 35,000 ppm. Inland seas such as the Great Salt Lake may have total dissolved solids of 200,000 ppm.

## 53. Impurities in Water

*a.* As water goes through its hydrologic cycle, it gathers numerous impurities. Dust, smoke, and gases fill the air and tend to contaminate rain, snow, hail, and sleet. As runoff, water picks up silt, chemicals, and disease organisms. As it enters the earth through seepage and infiltration, some of the suspended impurities may be filtered out, but at the same time, other minerals and chemicals are dissolved and carried along. It is now ground water in an underground deposit and, although it may now become less contaminated or polluted, it is not necessarily pure, and may contain disease organisms as well as harmful chemicals.

*b.* In addition to the impurities in water resulting from infiltration, many may be contributed by the carelessness of man. Examples of impurities created by man are garbage, sewage, industrial waste, insect sprays, and the use of chemical, biological, or radiological agents.

*c.* Impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria, and algae, and must be destroyed or removed from water that is to be consumed by troops. Table III (app. II) identifies the common impurities in water and summarizes their effect on water quality.

## Section II. WATER CHARACTERISTICS AND THEIR EFFECTS

### 54. Physico-Chemical Properties

Water takes on various characteristics and properties as it passes over and through the earth. These characteristics and properties vary, and are dependent on the materials encountered. They may be classified according to means of detection as physical (detected by one or more of the five senses) and chemical (de-

tested by chemical analysis). The most important *physical characteristics* are turbidity, color, odor, taste, and temperature. The most important *chemical characteristics* are acidity, alkalinity, hardness, and corrosiveness. Sometimes these two types of characteristics overlap; for example, iron in water is a dissolved mineral detectable by chemical analysis, yet its color and taste are also physical. This section discusses these characteristics and their causes.

## 55. Turbidity

a. Turbidity is a muddy or unclear condition of water, caused by particles of sand, silt, clay, or organic matter being held in suspension. The faster water flows, the more material it picks up and the larger the size of the pieces carried along. As water slows down, the larger particles settle out. When the flow stops, all but the finest particles settle out. Clay and silt remain suspended in water longest, because their particles are smallest.

b. The removal of turbidity is essential in the production of potable water. Such removal reduces contamination, extends the time between backwashing of filters, decreases chlorine demand, improves disinfection, and enhances the user acceptability of the finished water. The Army Medical Service requires turbidity removal because suspended particles often contain disease-producing organisms.

## 56. Color

Color in water is due to the presence of colored substances in solution, such as vegetable matter dissolved from roots and leaves, and to humus and iron salts. True color is that due to substances in true solution; apparent color includes true color and also that due to substances in suspension. Water taken from swamps, weedy lakes, and streams containing vegetation is most likely to be colored. Color may also be caused by industrial wastes, iron and manganese salts, and turbidity. This latter is an apparent color, rather than the true color caused by materials of vegetable origin. Color as such is harmless, but objectionable due to its appearance and to the taste and odors sometimes associated with it.

## 57. Odors and Taste

Taste and odors found in water are caused by algae (minute water plants), decomposing organic matter, dissolved gases, or industrial waste. Mineral substances may also be a cause. The chlorination of water may produce odors and tastes of its own or intensify those of the responsible organisms through destruction. Potability is not normally affected by the presence of odors and tastes. On the other hand, palatability is frequently affected, par-

ticularly when an agent such as bone or fish oil is present. Water containing one of these agents in noticeable quantities is unpalatable.

## 58. Temperature

Warm water tastes flat. Lowering the temperature of water suppresses odors and tastes and, therefore, increases its palatability. In the summer the temperature of deep lakes and reservoirs decreases sharply from top to bottom. By shifting the depth of intake, it may be possible to draw relatively cool water even during hot weather. Water should be drawn from the lower depths when possible. Cool water is more viscous than warm water and thus is more difficult to filter and coagulate. Water treatment rates should be reduced when water temperatures are less than 45° F.

## 59. Acidity and Alkalinity

a. Some of the impurities mentioned in paragraph 53 cause water to be either acid or alkaline in chemical composition. Since either condition has an important bearing on water treatment, the degree of alkalinity or acidity and their relationship in a given water source must be determined.

b. The *pH value* of a water sample is a measure of its acid or alkaline reaction. The pH values range from 0 to 14, 7 indicating neutrality; values less than 7, increasing acidity; and values greater than 7, increasing alkalinity. The Army comparator (figs. 51, 52, and 61) measures pH values of 4.4 to 9.2. The pH scale is shown in figure 42. An apparent “neutral” solution, having a pH value of 7 and reacting neither acid nor alkaline, may yet possess considerable alkalinity and acidity. The pH of water in its natural state varies from 5.5 to 9. Determination of the pH value assists in the control of corrosion, the determination of proper chemical dosages and adequate disinfection, and the detection of contaminants (pars. 81–93).

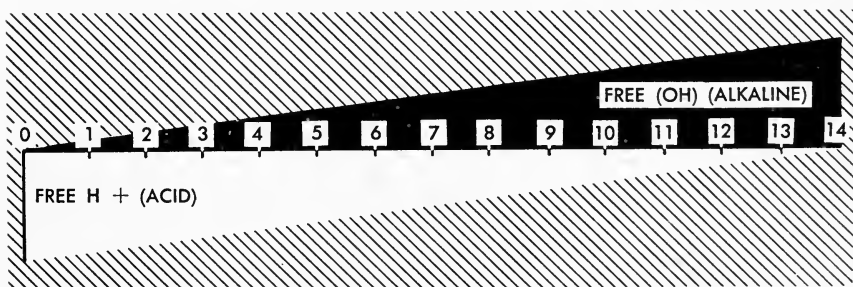


Figure 42. The pH scale.

## 60. Hardness and Other Characteristics Due to Dissolved Minerals

a. *Hardness.* The total amount of solids in water depends upon the material with which it has been in contact, the length of exposure, and the amount of carbonic acid present. Hardness, however, results from the presence of soluble salts of alkaline earths. The most common alkaline earths are calcium and magnesium. Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking, and produces scale in boilers and distillation units. Like alkalinity, hardness is expressed in terms of calcium carbonate. When the total hardness is greater than the carbonate and bicarbonate alkalinity, the amount of hardness equivalent to the alkalinity is called *carbonate hardness*. The amount of hardness in excess of this is called *noncarbonate hardness*. When the total hardness is equal to or less than the sum of the carbonate and bicarbonate alkalinity, there is no non-carbonate hardness; the total is all carbonate hardness. The following minerals cause hardness in ground and surface waters:

- (1) *Calcium carbonate.* Alkaline and only slightly soluble; causes carbonate hardness and alkalinity in water.
- (2) *Calcium bicarbonate.* Contributes to the alkalinity and carbonate hardness of water. Calcium bicarbonate when heated produces carbon dioxide and calcium carbonate. This calcium carbonate precipitates as scale in boilers and distillation units.
- (3) *Calcium sulfate or gypsum.* Causes noncarbonate hardness in water. Being more soluble in cold water than in hot, it separates from the water in boilers and forms scale on the boiler tubes.
- (4) *Calcium chloride.* Causes noncarbonate hardness in water. In steam boilers and distillation units, the heat changes it into an acid which rapidly pits the boiler tubes.
- (5) *Magnesium carbonate (magnesite) and magnesium bicarbonate.* Act the same in water as calcium carbonate and bicarbonate.
- (6) *Magnesium sulfate (epsom salts).* Adds to the non-carbonate hardness of water and causes boiler scale. In amounts greater than 500 parts per million in drinking water, it acts as a laxative.
- (7) *Magnesium chloride.* Has the same properties and effects as calcium chloride. However, the scales formed are somewhat softer than those formed by calcium chloride.

b. *Iron.* Iron is undesirable because it imparts a rusty color and objectionable taste to water. It also forms crusts in plumbing



and piping. When iron is present in water, bacteria may also be present. These organisms cause taste and odor as well as clogging of pipes. Methods of iron removal are discussed in paragraphs 109 through 115.

*c. Manganese.* While not encountered as often as iron, it is found in both surface and ground water. Its presence in water normally causes a grey or black color. Methods of removal are the same as for iron. The total concentrations of iron and manganese in potable water should not exceed 0.3 milligrams per liter.

*d. Sodium Carbonate (Soda Ash) and Sodium Bicarbonate (Baking Soda).* These increase the alkalinity of the water, thus raising its pH value. In steam boilers, hot water heaters, and distillation units, these minerals break down and release carbon dioxide, which corrodes metal tubes.

*e. Sodium Chloride (Table Salt).* Sodium chloride is of importance principally in connection with the salty tastes produced and in identifying the nature of noncarbonate hardness. If present in water in amounts greater than 400 ppm, the taste becomes noticeable.

*f. Sodium Sulfate (Glauber Salts).* This has a laxative effect when present in drinking water in amounts over 500 ppm. In large amounts, it causes foaming in boilers and distillation units.

## 61. Permissible Concentrations of Impurities

The concentration of chemical substances present in water for military water supply should not exceed the values shown below. If local conditions require the use of water containing higher chemical concentrations, authorization must be obtained from the Army Medical Service.

Copper .....	3.0 ppm
Iron and manganese .....	0.3 ppm
Zinc .....	15.0 ppm
Magnesium .....	125.0 ppm
Chlorides .....	250.0 ppm
Sulfates .....	250.0 ppm
Phenolic compounds .....	0.001 ppm
Lead .....	0.1 ppm
Hexavalent Chromium .....	0.05 ppm
Fluoride .....	1.5 ppm
Turbidity (silica scale) .....	10.0 units
Color (platinum-cobalt scale) .....	20.0 units
Nitrate-Nitrogen .....	20.0 ppm
Total Beta, Gamma Activity <sup>1</sup> .....	$3 \times 10^{-4}$ microcuries/ml
Total solids .....	500.0 ppm

<sup>1</sup> Water of this quality may be consumed safely for a period of 1 year. Individual variations in the amount of water consumed do not change this value. For greater or lesser periods of consumption, this value may be adjusted proportionally according to the time involved. This value is a combat standard only.

## 62. Dissolved Gases

The concentration of a gas in water is directly proportional to the concentration, or partial pressure, of the gas in the atmosphere in contact with the water surface. In general, this involves the water temperature, its salinity, and the altitude. The gases of primary interest to water supply are—

*a. Oxygen.* Large amounts of dissolved oxygen are found in rain water. The amounts in surface water vary greatly, depending on the amount and type of pollution, the degree of self-purification, the action of algae, and the temperature of the water. Polluted water will exhaust the oxygen supply, while clean water will contain much dissolved oxygen. Cold water contains larger amounts of dissolved oxygen than warm; as water temperature rises, the dissolved oxygen is released to the atmosphere. Decreased pressure on water has the same effect, releasing oxygen to the atmosphere. Dissolved oxygen causes the solution of metals and, especially in the presence of carbon dioxide, causes many metals to corrode.

*b. Carbon Dioxide.* The presence of carbon dioxide in water contributes to the degree of hardness and acidity of the water. Water acquires this gas in four ways: from the air by natural movements of water in contact with the air, such as currents and wave action; by contact with decomposing vegetation, which gives off carbon dioxide freely; by the reaction of alum and soda ash in the coagulation process; and by contact with the gas in underground deposits. A high carbon dioxide content usually makes water more corrosive to metals.

*c. Hydrogen Sulfide.* Hydrogen sulfide in solution lends a disagreeable taste and rotten-egg odor to water. Ground water absorbs sulfides by passing over sulfur-bearing rocks. Hydrogen sulfide is also responsible for the destruction of cement and concrete as well as the corrosion of metals. In small amounts, it is unpleasant but not dangerous. In large amounts it is harmful. Water which smells of hydrogen sulfide should be treated. Detection and treatment are described in chapter 5.

## Section III. CONTAMINATION OF WATER

### 63. Sources of Contamination

As explained in paragraph 51a, "contaminant" is a general term for a harmful impurity which makes water unfit for human consumption or domestic use. Contamination of water may be caused by disease-producing organisms, by industrial waste and other materials, or by chemical, biological, and radiological agents. Disease-producing organisms and industrial waste are discussed

below; contamination caused by chemical, biological, and radiological agents is discussed in paragraphs 66 through 69.

## **64. Waterborne Disease-Producing Organisms**

*a.* Water is a carrier of many organisms which cause intestinal disease. An epidemic of one of these diseases among Army troops can be more devastating than enemy action, and can cause great damage to morale as well as health. A heavy responsibility thus rests upon any water supply section, and vigilance over water purification equipment and procedures should never be relaxed. It is emphasized that water treatment methods to be used when certain chlorine-resistant organisms are encountered should be prescribed by a representative of the Army Medical Service. He will recognize or anticipate the presence of these disease organisms and recommend such additional chlorination or other treatment methods as may be necessary.

*b.* A waterborne disease rarely produces symptoms in its victim immediately after he has drunk the contaminated water. A period of time known as the incubation period must pass before the victim comes down with the disease. During this incubation period the disease organisms are growing and multiplying. Absence of symptoms for several days after untreated water has been drunk is, therefore, no guarantee that the water is safe. Also, absence of disease among the local inhabitants is no assurance of safety, because they may have developed immunity.

*c.* Types of waterborne diseases include: typhoid fever, paratyphoid fever, cholera, bacillary dysentery, amebic dysentery, common diarrhea, infectious hepatitis, and schistosomiasis. The last-mentioned disease is the result of infection by the larvae (cercariae) of the blood flukes (schistosomes) (fig. 43). The snail host of the schistosomes liberates large numbers of the cercariae into the water. When the water dries on the skin of human beings, the cercariae then burrow into the skin and infection occurs. Treatment of water contaminated with schistosomes, and the safeguarding of personnel while they are treating the water are discussed in chapter 5. See TM 3-216 for a detailed discussion of each disease.

## **65. Industrial Wastes**

*a.* Most industrial waste waters are derived from cooling, washing, flushing, extracting, impregnating, chemical treatment, and similar operations. They are as varied in quantity and nature as the products and processes of the industrial plants from which they drain. Toxic metals and chemicals discharged as industrial waste may destroy the biological activity of streams and cause receiving waters to become unfit for further use. Organic chem-

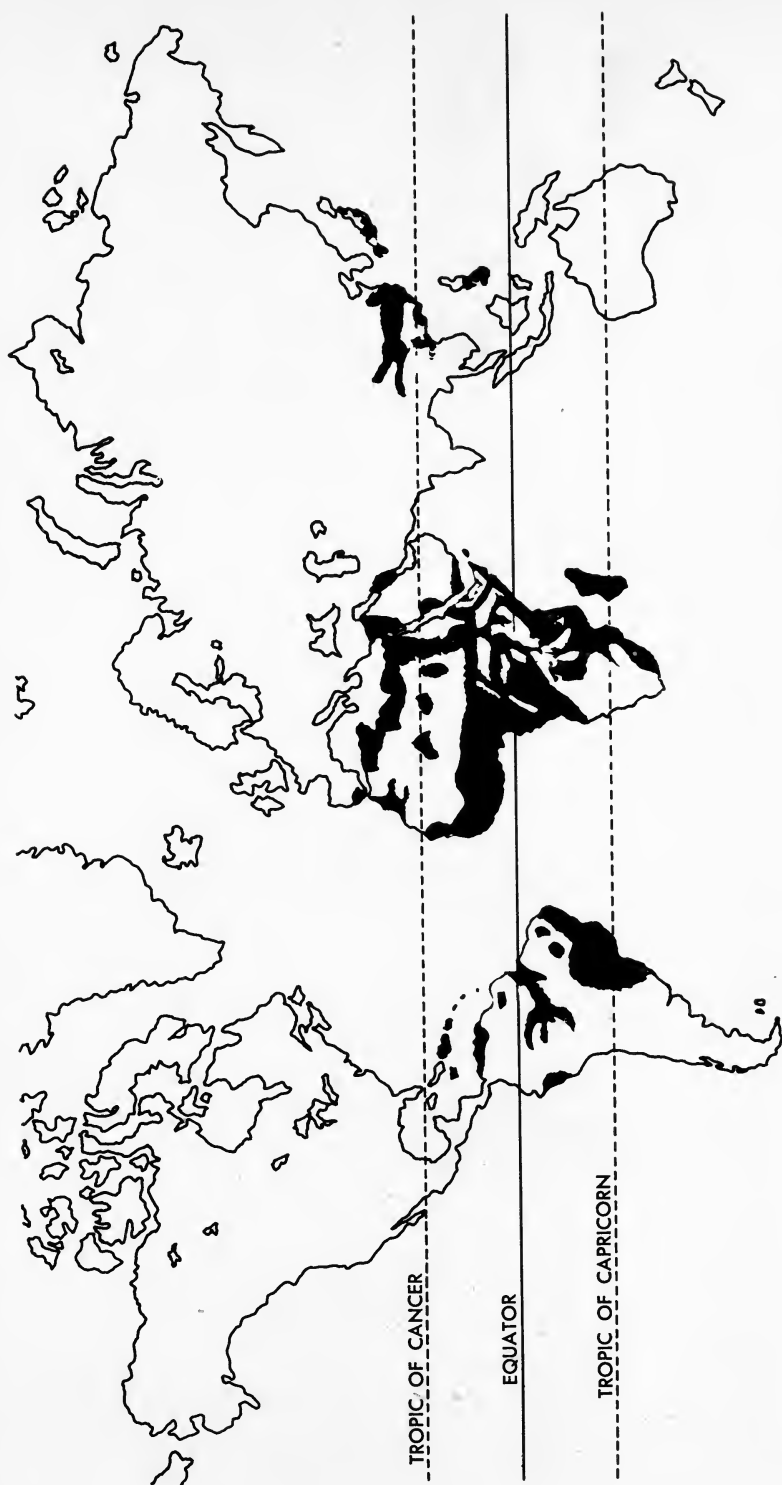


Figure 43. Geographical distribution of three types of schistosomes.

icals may impart to receiving waters tastes and odors that are almost impossible to remove by water purification. Strong acids and alkalies may be corrosive to metals.

b. The use of raw water sources containing measurable quantities of industrial waste should be avoided. If such a source must be used, advice as to treatment should be obtained from the Army Medical Service. Consideration should be given to—

- (1) *Phenolic compounds.* Acid mine waste and industrial waste of which coal and wood distillation form a large part are a principal source of phenolic input to water sources. Very minute quantities of phenols will impart objectionable medicinal or phenolic tastes to water which are intensified by chlorination.
- (2) *Chromates and cyanides.* Chromates, or hexavalent chromium, and sodium cyanide are widely used in electroplating and other electrolytic operations. The concentration and composition of the poisonous waste waters vary widely. About one mg/1 (one ppm) of chromate (as  $C_r$ ) or cyanide (as CN) appears to be the permissible limit of these substances that would be left in sewage that is to be treated biologically (self-purification). The Army permits a maximum permissible concentration of .05 ppm of hexavalent chromium in water that is to be treated. The addition of acids to cyanide waste releases a highly toxic hydrogen cyanide gas.
- (3) *Lead.* Lead is a cumulative poison and, if present in drinking water, even in small quantities, may give rise to symptoms of lead poisoning. Lead in water is dangerous, must be tested for, and, if present, eliminated. However, since natural water rarely contains lead, poisoning will not normally occur unless lead is used in water supply construction. Oxygen and carbonic acid, always present in water, will dissolve lead. Soft or acid water, such as rain or swamp water, is also prone to dissolve lead. Thus lead used in roof construction, and lead gutters and downspouts, can be sources of solution of lead if rainwater is used as a water source. When existing water facilities are utilized (ch. 7), lead from these sources may be present in the water supply.
- (4) *Other industrial waste.* Other typical industrial waste are arsenates, ammonia, cresols, sulfides, oil field brines, coal mine drainage, and the residues of iron and copper smelting. Methods of detection and treatment are discussed in chapter 5.

## Section IV. CONTAMINATION BY CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL AGENTS

### 66. Importance to Water Supply

Should chemical, biological, or nuclear warfare be waged during future conflicts, the water supply of any given area would, in all likelihood, become contaminated. A water source contaminated by CBR agents can cause disease, serious injury, or death to a consumer. Effective means for determining the presence of CBR agents, followed by proper decontamination procedures, can reduce or eliminate the hazards caused by these agents. A detailed discussion of agents and means of dissemination can be found in FM 21-40.

### 67. Chemical Agents

Toxic chemical agents include mustard, nitrogen mustards, lewisite, hydrogen cyanide, and the nerve agents. The blister gases, nerve gases, and agents containing cyanide are most dangerous because they are highly poisonous, are soluble in water, and either are slow to decompose in solution or remain poisonous after decomposition. Water supplies are likely to become contaminated as an incidental result of widespread chemical attack, rather than as a result of direct attack on the water supply.

### 68. Biological Agents

More recent times have seen accelerated research and development in biological contaminants and means of dissemination. Biological warfare, if employed today, can be of major significance, and field water sources would undoubtedly be contaminated. The agents which could be used include the spectrum of pathogenic organisms. Water supply personnel must be alert to detect indications of the use of biological agents, as described in FM 21-40. If indications are present, a representative of the Army Medical Service should be contacted immediately.

### 69. Radiological Agents

a. Although nuclear weapons have been employed in combat, there are no reliable data as to the effect of nuclear explosions on field water supplies. However, available fallout data leave no doubt that contamination of water supplies by this means must be considered. Since radiation is not detectable by the human senses, instruments and laboratory tests are necessary to determine its presence.

b. A nuclear attack over or near a source of water supply will probably cause its contamination with radioactive materials. A

nuclear explosion could cause contamination by any of the following, listed in the decreasing order of importance to the water point operator:

- (1) Fallout of fission products.
- (2) Induced activity in the water and surrounding soil.
- (3) Blow-in or wash-in of radioactive dust.
- (4) Fallout of unfissioned uranium or plutonium.

The magnitude of contamination is dependent upon the yield of the weapon, the location of the detonation with respect to the water source, and whether it is a surface or subsurface burst. (Fallout from an airburst need not be considered here.)

c. Detection of radioactive materials in water, the maximum permissible concentrations for extended periods of use, and the means of decontamination are discussed in chapters 5 and 6.

## CHAPTER 5

### WATER TREATMENT PROCESSES

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#### Section I. INTRODUCTION

#### 70. Self-Purification

*a. Significance.* Under favorable conditions, any polluted body of surface water—stream or river, lake or pond—will rid itself of a certain amount of its pollution by means of natural processes. This self-purification cannot be depended upon to bring about complete recovery (purification), but it may well improve the water quality sufficiently to ease the load on mechanical purification equipment.

*b. Streams and Rivers.*

- (1) When sewage is discharged into water, a succession of changes in water quality takes place. If the sewage is emptied into a lake in which currents about the outfall are sluggish and shift their direction with the wind, the changes occur in close proximity to each other and, as a result, the pattern of changes is not crisply distinguished. If, on the other hand, the water moves steadily away from the outfall, as in a stream, the successive changes occur in different river reaches and establish a profile of pollution which is well defined. However, in most streams, this pattern is by no means static. It shifts longitudinally along the stream and is modified in intensity with changes in season and hydrography.
- (2) When a single large charge of sewage is poured into a clean stream, the water becomes turbid, sunlight is shut out of the depths, and green plants, which by photosynthesis remove carbon dioxide from the water and release oxygen to it, die off. Depending on the stream velocity, the water soon turns nearly black. Odorous sulfur compounds are formed and solids settle to the bottom, forming a sludge. The settled solids soon decompose, forming gases such as ammonia, carbon dioxide, and methane or



marsh gas. Scavenging organisms increase in number until they match the food supply. The oxygen resources are drawn upon heavily and, when overloaded, become exhausted. Life in such waters is confined to anaerobic bacteria, larvae of certain insects such as mosquitoes, and a few worms. There are no fish; turtles are generally the only forms of higher life here.

- (3) This condition is known as the zone of degradation. In a second zone, or zone of decomposition, more solids settle out, the water becomes somewhat clearer, and sunlight penetrates the surface. Oxygen is absorbed from the atmosphere at the air-water interface permitting the establishment of aerobic conditions. The aerobic bacteria continue the conversion of organic matter into nitrates, sulfates, and carbonates. These, together with the carbon dioxide produced by decomposition as well as by bacteria and plant life, are food sources. With sunlight now penetrating the water, and with abundant food, algae begin to flourish and form a green scum over the surface.
- (4) In a third zone, or zone of recovery, algae become more numerous and self-purification proceeds more rapidly. Green plants utilizing carbon dioxide and oxygen will liberate in the day time more oxygen than is consumed, thus hastening the recovery of the stream. Simultaneously, fish that require little oxygen, such as catfish and carp, are also found. As the dissolved oxygen increases, more types of fish appear. After recovery, in the zone of cleaner water, fish find the stream highly favorable, as the algae support various aquatic insects and other organisms on which fish feed. The water is clear or turbid according to concentration of algae, and may have odor for the same reason.
- (5) Throughout the stages of recovery or self-purification, disease organisms are greatly reduced in number because they lack proper food, and experience unfavorable temperatures and pH values of water. However, the water is still dangerous since all disease organisms have not perished.

*c. Lakes and Ponds.* Self-purification in lakes and ponds is brought about by the same processes as in rivers and streams. However, currents are not as strong, and sedimentation plays a larger role. Large deposits of sludge, dead algae, and other organic material build up on the bottom. In deep lakes, self-purification is aided by seasonal "overturns." This is simply an exchange of bottom water for surface water which occurs in the spring and

fall, caused by the difference in the temperature of the water at the surface and bottom of deep lakes.

## 71. Field Water Purification

a. The primary purpose of field water purification is to make water safe for human consumption by removing or killing harmful bacteria which may cause sickness or death. The amount and type of treatment called for depend upon the quality of the raw water, the quantity of purified water needed, and to some extent, the degree of purification required.

b. The equipment used for field water purification is discussed in this chapter only to the extent needed to properly describe treatment procedures. The equipment was discussed in detail in paragraphs 36 through 38. For normal field water purification of surface waters, either continuous flow type or the batch type equipment is used. The continuous flow type equipment performs coagulation, sedimentation, filtration, and disinfection within one mechanized set of equipment. The batch type equipment accomplishes the same, but is less mechanized and less compact. Distillation or ion exchange equipment is required for brackish or sea water. Army equipment is capable of producing water at least as potable and palatable as that of most municipal systems, and provide it in adequate quantities.

c. The four basic steps used in field water purification are: coagulation, sedimentation, filtration, and disinfection. Demineralization, may be required when the source has a high content. Each of the basic steps is explained in paragraphs 76 through 80.

## Section II. UNITS OF MEASUREMENT

### 72. System of Measuring Chemicals

In water treatment, the amounts of chemicals used must be carefully controlled. Therefore, a uniform system of measuring chemicals has been devised for use in all water treatment procedures involving chemicals. The weight of the chemicals added to each gallon of water is usually such a small fraction of a pound that the grain is used as the unit of measurement, and quantities are expressed in grains per gallon. In larger chemical doses, quantities are expressed in pounds per million gallons.

### 73. Definition of Units of Measurement

a. *Parts Per Million.* A common unit of measurement is "parts per million" (ppm), a ratio by weight of a substance per million parts by weight of water. The expressions, "parts per million" and "ppm," are abbreviations of "parts by weight of substance

per one million parts by weight of water.” The word “part” refers to similar units and may be used to indicate any unit of measure. For example 1 pound of alum per million pounds of water, or 1 grain of alum per million grains of water both mean 1 ppm. Since the gallon is not a unit of weight, the weight of a gallon of water is used to convert pounds per million gallons to parts per million. A gallon of water weighs 8.34 pounds, so 1 million gallons weigh approximately 8,340,000 pounds. Therefore, 8.34 pounds per million gallons equals 1 ppm.

*b. Grains Per Gallon.* As there are 7,000 grains in each pound, 1 grain per gallon equals 1/7000th pound per gallon, or approximately 143 pounds per million gallons ( $1/7000 \times 1,000,000 = 143$ ). Since 143 pounds per million gallons equals 1 grain per gallon, and since 8.34 pounds per million gallons equals 1 ppm, 1 grain per gallon equals 143 divided by 8.34 or 17.1 ppm.

*c. Milligrams Per Liter.* The term “milligrams per liter,” also expressed “mg/l” is coming into use and is frequently encountered in water supply literature. It is used exclusively in civilian practice. A liter is a measure of capacity in the metric system, roughly equivalent to a U.S. quart. The milligram is a measure of weight, also in the metric system. Since a liter of water weights 1,000,000 milligrams, the term mg/l is exactly equivalent to parts per million, as far as relationship between units and the whole is concerned, because each signifies “parts by weight of substance per one million parts by weight of water.”

## 74. Conversion Guides for Measuring Chemicals

*a. Conversion Table.* It is often necessary to convert from one unit of measurement to another in water treatment processes. The relationships and figures given above have been arranged in the following table for this purpose.

To convert	To—		
	Grains per gallon	Parts per million (ppm)	Pounds per million gallons
	Multiply by—		
Grains per gallon . . . . .	1	17.1	143.0
Parts per million . . . . .	0.058	1	8.34
Milligrams per liter . . . . .	0.058	1	8.34
Pounds per million gallons . . . . .	0.007	0.12	1

*b. Dosage Formulas—Coagulants.* Dosages of chemicals used as coagulants are usually expressed in grains per gallon. The dosage in pounds can be determined from the following operation:

Pounds of chemical required =

$$\frac{\text{gallons of water treated} \times \text{dosage in grains per gallon}}{7,000}$$

Assuming a dosage of 8 grains per gallon is required for a total of 3,000 gallons, the pounds of chemical required

$$\begin{aligned} &= \frac{3,000 \times 8.0}{7,000} = \frac{24,000}{7,000} = 3 \frac{3}{7} \text{ pounds} \\ &= 3 \text{ pounds } 7 \text{ ounces approximately} \end{aligned}$$

For field approximations, 1 grain per gallon can be considered equal to one-seventh of a pound or approximately 2 ounces per 1,000 gallons.

*c. Marks—Field Measurement of Pounds of Chemicals.*

- (1) Since no balance or other weighing instrument is issued with water supply equipment in the field, it is necessary to use a less common means of weighing pounds of chemical. Water displacement in relation to specific gravity of the chemical is a convenient technique.
- (2) Ammonium alum (alum) has a specific gravity of 1.6, that is, a given volume of alum is 1.6 times as heavy as an equal volume of water. Thus, 1 pound of alum occupies the same volume as 10 ounces of water.

$$\frac{16 \text{ ounces water}}{1.6 \text{ (sp.gr. alum)}} = 10 \text{ ounce marks}$$

Thus the standard 32-ounce measuring cup may be used to measure out a pound of alum. The cup is filled to the 16-ounce mark with water. Crystalline alum is added to the cup until the water level reaches the 26-ounce mark. The cup now contains a pound of alum. Care must be taken that all crystals are completely under water. The following formula can be used to measure any given quantity of alum:

$$\text{pounds of alum} \times 10 = (\text{ounce}) \text{ marks of alum}$$

The constant, 10, is obtained by dividing ounces in a pound of water by the specific gravity of the chemical  $\left( \frac{16}{1.6} \right)$

- (3) This technique may be used to measure any solid chemical which does not chemically react with water, provided that the specific gravity of the chemical is known. The specific gravity of the soda ash as used in the field is 2.4. By dividing this specific gravity into the ounces in a pound, a constant of 6.7 is obtained:

$$\frac{16 \text{ ounces water}}{2.4 \text{ sp gr soda ash}} = 6.7 (\text{ounce}) \text{ marks}$$

Accordingly, to find the given marks of water displaced by a quantity of soda ash, the following formula is used:  
 $\text{pounds of soda ash} \times 6.7 = (\text{ounce}) \text{ marks of soda ash}$

d. *Dosage Formulas—Chlorine.* Chlorine dosages are given in ppm rather than grains per gallon. To compute the amount of chlorine needed, the following formula is used:

Pounds of chlorine=

$$\frac{\text{Gallons of water} \times 8.34 \times \text{dosage of chlorine in ppm}}{1,000,000}$$

When using hypochlorites, such as calcium hypochlorite, the amount used must be increased by dividing by 0.7 because hypochlorites contain only 70 percent chlorine. The following formula may be used to determine the amount, expressed in ounces, of hypochlorite required.

$$\text{Dosage in ounces} = \frac{\text{Pounds of chlorine} \times 16}{0.7}$$

## 75. Relation Between Pressure and Head

Pressure is weight expressed as pounds or grams of force exerted upon a given point. The term "head," in hydraulics, refers to the vertical distance from the bottom of a column or system of liquid to the surface of that liquid. Intensity of pressure is often expressed as pounds per square inch (psi). Since 1 cubic foot of water weighs 62.4 pounds, a column of water 1 inch square and 1 foot high would weight 0.43 pounds (62.4 pounds divided by 144 square inches). This column is said to exert 0.43 pounds per square inch pressure. Hence, *1 foot of head will exert 0.43 psi.* Conversely a pressure of 1 pound per square inch would be exerted by a column of water 2.31 feet high. (1.0 divided by 0.43 psi). Feet of head may be converted to pounds per square inch simply by multiplying the number of feet by a constant 0.43. If a pressure factor expressed as pounds per square inch is given, and feet of head is desired, conversion can be made by multiplying pressure (psi) by a constant 2.31.

## Section III. BASIC STEPS IN TREATING WATER

### 76. Coagulation

a. *Definition.* Coagulation is the process of preparing water for rapid sedimentation through the use of chemicals. Certain chemicals, when added to water, cause the small suspended impurities to gather into larger particles and then settle out, or be drawn off, more rapidly. The coagulation process is widely used in water treatment plants. In the Army, the standard chemicals used to bring about coagulation are ferric chloride for the continuous flow method and ammonium alum for the batch method.

b. *Flocculation.* The ferric chloride or alum, whichever is being used, combines with the alkalinity present in the water to form an

insoluble jelly-like substance called "floc." The chemical process which takes place in the water is called "flocculation." When the water does not have a sufficient amount of natural alkalinity to react in this way with the coagulant, alkalinity is added to stimulate the process. The continuous flow method employs calcium carbonate, commonly called pulverized limestone, for this purpose. With the ammonium alum used in the batch method of purification, the source of alkalinity is soda ash (table VIII). The floc attracts and traps the suspended silt, disease organisms, and other impurities. When it first forms, floc is in very small particles which give the water a reddish or milky appearance, depending on whether ferric chloride or alum is the coagulant. The water must be agitated, or otherwise kept moving, to cause the floc particles to coalesce into bigger pieces, and thus produce a heavy floc rapidly. The movement is accomplished mechanically in the continuous flow method. In the batch method, a high rate of inflow is used and the influent hose is directed along the wall of the tank so that a circular water movement is set up in the tank (fig. 44).

## 77. Filtration

a. Filtration consists of passing the water through some porous



*Figure 44. Basket method of adding coagulating chemicals—batch method of water treatment.*

material to remove the suspended impurities. Filtration is one of the oldest and simplest procedures known to man for removing suspended matter from water and other fluids.

b. The simplest form of water filter is the sand filter. This filter resembles a small reservoir, the bottom of which is a bed of filter sand which in turn rests on a bed of well graded aggregate with the largest size aggregate being at the bottom. An underdrain system of tile or brick is provided under the gravel to collect the water from the filter area. This underdrain system consists of a header or main conduit extending across the filter bed. Means are provided for regulating the flow of water out of the filter through this header and also for controlling the rate of flow on to the filter. This allows the filter to be operated at controlled rates which should not exceed 3.0 gpm per square foot of filter area. An average filter bed consists of about 12 to 20 inches of gravel and 20 to 40 inches of sand. The depth of water over the sand bed varies from 3 to 5 feet.

c. The most effective filtration system ever devised by the Army and one of the most effective portable systems in existence is the diatomite filter unit (fig. 45). This filter equipment, in different versions, is used in both the continuous flow and the batch treatment units. In the diatomite filter, water is passed



*Figure 45. Filter unit—diatomite set No. 4—disassembled*

through a layer of diatomaceous silica, also called diatomaceous earth, which consists of skeletal remains of minute algae (diatoms), found in marine deposits that have lifted above sea level.

d. The diatomite type filter accomplishes highly efficient filtration. Properly operated diatomite filters are capable of removing from coagulated and settled water, amebic cysts, the cercariae of schistosomes, and approximately 90 percent of the bacteria, as well as producing water with less than one unit of turbidity.

## 78. Disinfection

a. *Need for Disinfection.* In addition to coagulation, sedimentation, and filtration, water must undergo an additional treatment step: disinfection. This is necessary because no combination of the other two steps can be relied upon to remove all disease-producing organisms from water, and also because there is danger of recontamination during handling before consumption. Residual disinfection utilizing chlorination is the final step in all Army water treatment processes (including distillation). Under emergency or field conditions, water may be disinfected with iodine or by boiling.

b. *Disinfection by Natural Processes.* A certain amount of natural disinfection of water takes place in nature by the ultraviolet rays in light and by the oxygen that is absorbed into water. (See description of self-purification in par. 70.) However, the amount of germicidal action thus accomplished is relatively small and unreliable, and natural disinfection is not, therefore, an important factor in water purification.

c. *Disinfection by Boiling.* Boiling is a practical means of disinfecting small quantities of water in the field by individual soldiers. Under such conditions, water should be boiled at least 15 minutes. Upon cooling, the boiled water should be kept in a covered uncontaminated container. Boiling is obviously a difficult way to disinfect large quantities of water.

d. *Chemical Disinfection.* The most satisfactory means of water disinfection and provision of a residual is by means of a chemical disinfectant. The efficiency of the disinfection process is dependent upon numerous factors which include the chemical agent used, the contact time, the type and concentration of microorganisms, the pH and temperature of the water, the presence of interfering substances, and the degree of protection afforded organisms from the disinfecting solution by materials in which they are imbedded. Therefore, various concentrations of disinfectant are required depending upon the local environmental conditions and the amount of particle removal effected.

e. *Chlorine as a Disinfectant.* Chlorine is the most commonly used chemical for disinfection of water. It is employed in field



water supply in the form of calcium hypochlorite, a powder available commercially. The chlorine compound is very active chemically and readily dissolves in water. When the calcium hypochlorite is dissolved, the chlorine goes into solution and a calcium carbonate sludge settles out. The chlorine is present in the solution as hypochlorous acid or hypochlorite ion, depending on the pH, both of which are powerful oxidizing substances. The chlorine available in either of these two forms rapidly oxidizes the organic and inorganic matter including the bacteria in the water. In this reaction the chlorine is converted to chloride and is no longer available as a disinfectant. The organic matter as well as such material as iron and manganese consume the chlorine. The use of chlorine makes it possible to introduce an accurately measured dosage to insure the destruction of disease-producing organisms as well as provide a readily measured residual to safeguard against recontamination during further handling.

(1) *Residual chlorine.* As indicated in *e* above, residual chlorine is the amount of unreacted chlorine remaining at a specified time after the chlorine compound is added. Chlorine in aqueous solution is highly unstable. It may change quantitatively and qualitatively under numerous conditions, including the presence of other elements or compounds. The total residual chlorine in the water can be chemically divided into several types:

(a) *Free available chlorine.* Refers to hypochlorous acid and hypochlorite ion present in the water. These are the most effective disinfecting forms of chlorine. The free available chlorine is a rapid-acting type, important because it can be relied upon to destroy bacteria relatively quickly, and thus is active during the period immediately following chlorination. The relative amount of each present in the water is dependent upon the pH value of the water. It is important to remember that when the pH is raised the quantity of free available chlorine required to kill the same number of microorganisms increases. With decreasing temperature the same situation of increasing dosage to maintain the same kill is encountered. If the contact time is varied, then the dosage applied may also be changed. For example, to shorten the contact time the dosage would have to be increased.

(b) *Combined available chlorine* results from the presence of ammonia or organic nitrogen that will react to form simple chloramines. Thus the term "combined available chlorine" arises from the fact that the chlorine has combined with another substance. Chloramines

are a slower acting and less active form of disinfectant. Therefore, a much higher concentration than that of free available chlorine is needed to produce the same germ destroying effect. The specific chloramines present are also a function of pH.

- (c) *Total available residual chlorine* is the sum of the free available chlorine and the combined available chlorine. Paragraph 86 describes the tests for determining residual chlorine.
- (2) *Chlorine dosage*. Dosage is the amount of chlorine added to water to satisfy the chlorine demand as well as to provide a residual after a specified time. The amount required to disinfect water varies with the organic content and pH value of the water, the temperature, the time of contact, and the chlorine residual required. The dosage is usually stated in terms of parts per million (ppm).
- (3) *Chlorine demand*. The chlorine demand of water is the difference between the quantity of chlorine applied in water treatment and the total available residual chlorine present at the end of a specified contact period. (Terms are defined in (1) above.) The chlorine demand is dependent upon the amount of chlorine applied (amount applied is dependent on the free available and combined available chlorine), the nature and the quantity of chlorine-consuming agents present, the pH value and temperature of the water (high pH and low temperatures retard disinfection by chlorination). For comparative purposes, it is imperative that all test conditions be stated. The smallest amount of residual chlorine considered to be significant is 0.1 ppm. The relation of the demand to the length of the contact period is discussed in (4) below. Some of the chlorine-consuming agents in the water are nonpathogenic, but this bears no relationship to the fact that they contribute to the total chlorine demand of the water. Army chlorination policy requires that for field water supplies the chlorine demand must be satisfied.
- (4) *Disinfecting time*. Chlorine demand in most water is likely to be largely satisfied 10 minutes after chlorine is added. After the first 10 minutes of chlorination, disinfection continues but at a diminishing rate. A standard period of 30 minutes' contact time is used to assure that highly resistant or highly disease-producing organisms have been destroyed, providing a high enough dosage has been applied. Given a sufficiently large chlorine content,

and if certain other conditions are met, even such special water purification problems as the presence of amebic cysts or schistosomes will be solved with the 30-minute contact period (par. 113).

*f. Emergency Treatment Methods Utilizing Water Sterilizing Bags, Canteens, and Other Water Containers.* These methods do not provide for removal of impurities by coagulation and filtration. The entire reliance for rendering the water safe for consumption is placed on the disinfection process. Sufficient chlorine is added to the water so that the residual, after 30 minutes of contact, will be at least five parts per million of total chlorine (par. 114). Under certain conditions, such as the presence of highly resistant disease-producing microorganisms or adverse environmental conditions, the surgeon of a major command (field army or higher) will designate such higher residuals as may be necessary.

## 79. Sedimentation

*a.* Plain sedimentation is the natural settling of solids heavier than water without the addition of chemical coagulants. Solids heavier than water are held in suspension while in moving water, but gradually settle to the bottom as the water velocity is reduced. The time required to clarify water by sedimentation depends on the size of the suspended particles and their specific gravity. Large and heavy particles settle in a few minutes once the water has become still, whereas very small particles such as clay and silt may remain in suspension for several days.

*b.* Plain sedimentation is not ordinarily used by the Army as a separate step in water treatment because the long period required for complete settling would call for an impractical number of settling tanks. However, in emergency situations, such as the necessity of taking water from a swift-flowing stream which is heavily silt-laden after a rainstorm, special sedimentation tanks may be set up as a first step. This initial removal of turbidity reduces the load on the coagulation and filtration steps of the water treatment process and the frequency of filter backwashing is reduced.

## 80. Demineralization

Demineralization is the removal of substantially all ionizable materials that will leave a residue on evaporation. Demineralization may be employed to soften water, to remove iron and manganese, and to reduce the concentration of flourides to tolerable or desirable values. It is also used in the military for the removal of radio-active materials from water. Demineralization may be accomplished electrochemically, or by distillation. Distillation units are available for use by the Army.

## Section IV. STANDARD QUALITY CONTROL TESTS FOR FIELD USE

### 81. Purpose of Tests

a. Performance of the various processes and steps for treating water, and even conducting a proper reconnaissance for selection of a water point, all require an understanding of the characteristics and quality of the raw water itself: its pH value, chlorine demand, its turbidity and salinity, and the various contaminants it can contain. In the field, these characteristics are determined by use of the water quality control set, reconnaissance and routine control. This standard field water quality testing set is a compact, portable chest of equipment. With it the operator can identify the impurities in a given water. In some instances, he can measure amounts of the impurities, while both qualitative and quantitative analyses are possible in the case of the contaminants. Type of treatment is based on results of these tests.

b. Tests made with this set may be divided into three groups: routine control, salinity, and toxic chemical agent contamination.

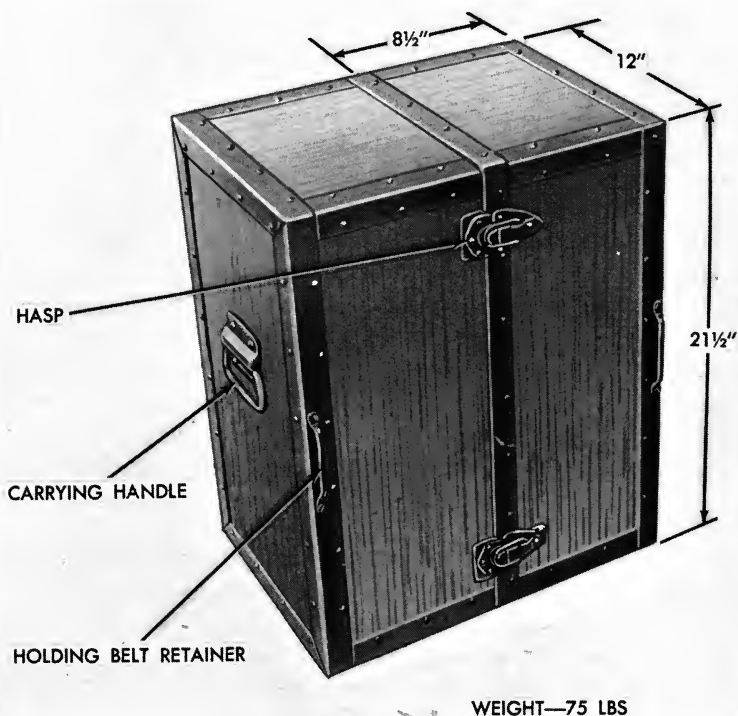


Figure 46. Water quality control set, reconnaissance and routine control—chest closed.

(Chemical agents are discussed in ch. 6.) The routine control tests are for turbidity, pH, chlorine residual, and coagulation. The salinity tests are for soap hardness, alkalinity, chlorides, and sulfates. The contamination tests are for mustard, nitrogen mustards, arsenicals, nerve gas agents and other contaminants which might be deposited in the water source as a result of chemical warfare or use of agricultural control chemicals such as insecticides. Special tests for chlorine demand and pH are used with the contamination tests, because these two factors may be indicative of certain toxic chemical agents. The toxic chemical agent contamination tests are discussed in chapter 6.

## 82. Water Quality Control Set, Reconnaissance and Routine Control

a. The water quality control set, reconnaissance and routine control, is contained in a small reinforced plywood chest. Every piece of equipment has a definite position in the chest and after use should be returned to its proper place. Figures 46 and 47 show two views of the chest, one closed and one open, and figures 48, 49, and 50 show the various drawers and their contents. The contents of the chests are listed in the following tables: table IV—supply

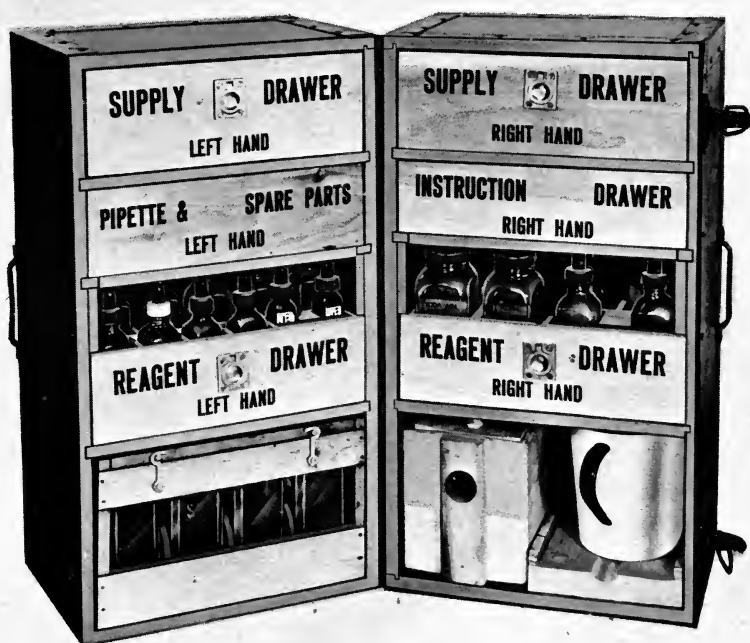


Figure 47. Water quality control set, reconnaissance and routine control—chest open.

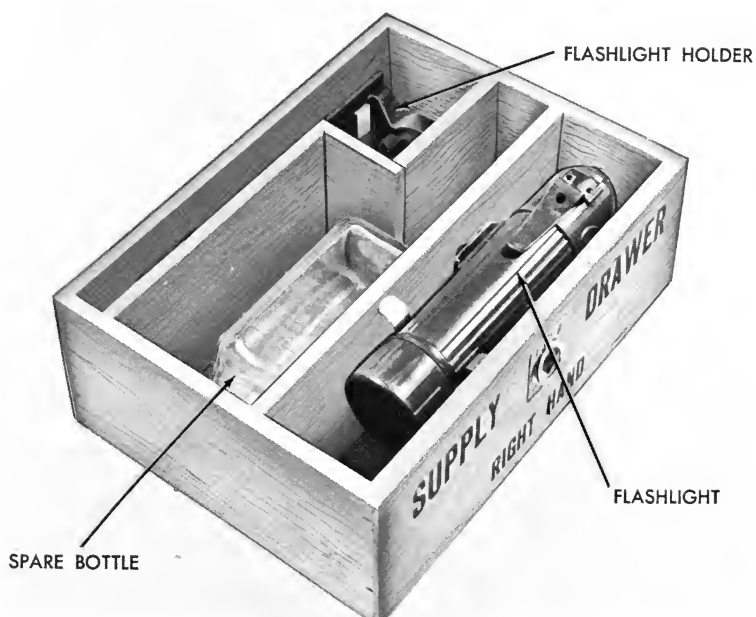


Figure 48. Water quality control set, reconnaissance and routine control—drawers and contents.

TM 5-700

LOADING PLAN

PIPETTE TRAY

PIPETTES

SPARE PARTS

TEST TUBE BRUSHES



89 *Figure 49. Drawers containing pipettes, spare parts, and instructions—water quality control set reconnaissance and routine control.*

drawers; table V—pipette and spare parts drawer and instruction drawer; table VI—reagent drawers; and table VII—bottom shelves, A and B. A detailed loading plan is given in the instruction drawer—the right hand drawer second from the top. This plan is helpful in making sure that everything is put away in its proper place each time, after the set has been used.



*Figure 50. Reagent drawers—water quality control set, reconnaissance and routine control.*

b. A complete list of the materials and equipment contained in the set is provided in Supply Manual 5-4-6630-SO1. Included are reagents and laboratory equipment required for the various tests, coagulation test set, turbidimeter, and chemical agents water testing kit. The color comparator for determination of pH value and chlorine demand is issued separately.

### 83. Use of Comparator

a. *Principle of Use.* In the comparator (fig. 51), circular lenses of colored glass placed in several removable plastic disks provide the means for checking and interpreting the color of a sample of water which has been impregnated with an indicator solution. The



indicator solution, when added, causes the sample of water to change color in accordance with the chlorine content or pH value of the water. The proper disk for reading the desired information is inserted in the comparator and rotated alongside the water sample until the colored glass and the color of the sample match.

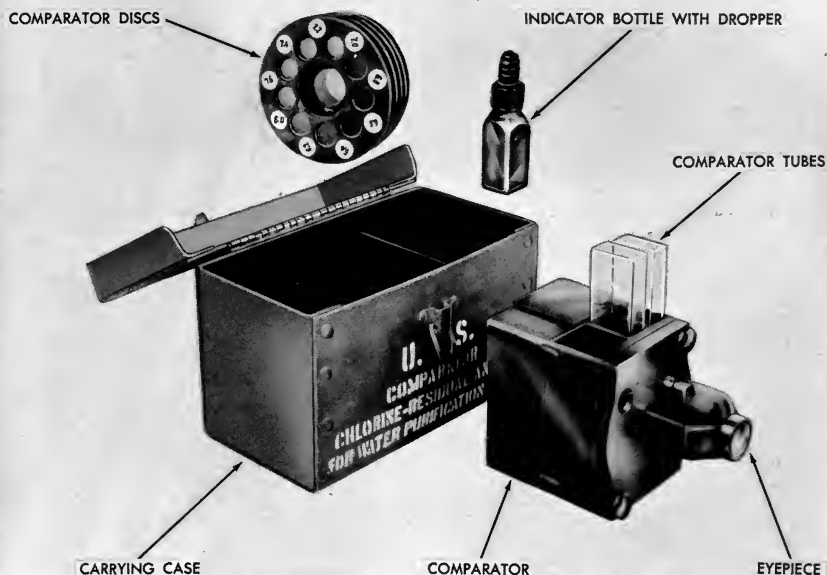


Figure 51. Color comparator, shown with case.

*b. Procedure.* To use the comparator, wash the tubes to be used in the water to be tested. The following steps are illustrated in figure 52. Fill a dropper to the graduated mark with indicator solution; this equals  $\frac{1}{2}$  ml. Put the solution in one of the tubes; then fill the second tube up to the etched mark with the water to be tested. Pour this water into the tube containing the indicator solution, thus mixing the solution and the sample of water. Now fill the second tube again to the etched mark, with an uncolored sample of water. Place both tubes in the comparator with the second tube behind the colored glass disk and the tube containing the indicator behind the viewing hole. The disk is rotated as stated above, and when the colors match, the numerical reading is taken directly from the disk.

## 84. Turbidity Tests

*a. Basic Features.* The turbidity test is used to show the amount of suspended matter present in raw water, and also to determine the amount removed from treated water. The test may



①

Placing indicator solution in clean tube.



②

Adding water to indicator solution. Tube is filled up to etch mark.



③

A clear sample of the water being tested has been placed in second tube (right). Tube on left contains mixture of indicator solution and water produced in steps 1 and 2.



④

Placing both tubes in comparator.



⑤

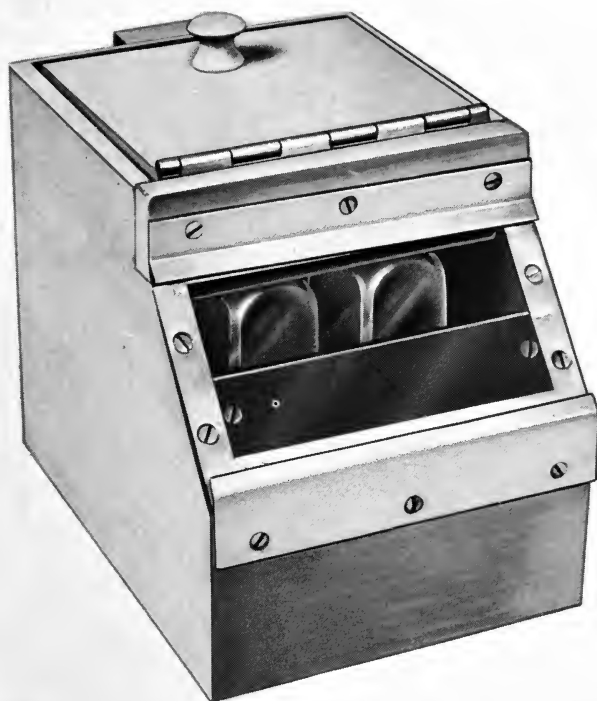
Obtaining reading from comparator by rotating color disk until color of indicator solution is matched.



⑥

The pH value is read directly on the color disk. Value of this sample was 7.2.

*Figure 52. Use of color comparator for pH determination.*



TURBIDIMETER



MEASURING CUP

*Figure 53. Turbidimeter and measuring cup.*

be made with the white porcelain cup with its black enameled dot, or by employing the turbidimeter and standard turbidity solutions (fig. 53). Rapid approximate readings *only* can be made by using the cup.

b. *Turbidity Determination by Use of Measuring Cup.*

- (1) The measuring cup can be used to determine whether raw water has more or less than 100-ppm turbidity. If the black spot cannot be seen when the cup is filled to the top with the water sample, the turbidity is 100 ppm or

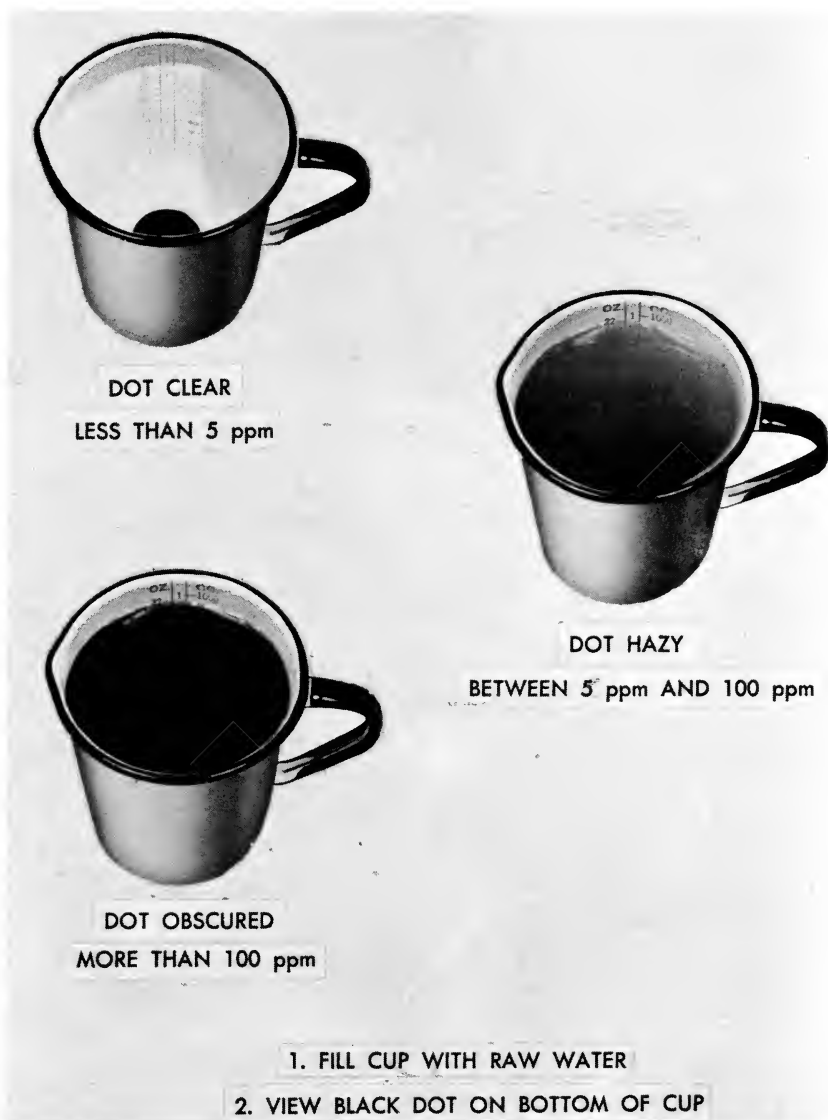


Figure 54. Turbidity determination by use of measuring cup.

over. The turbidity is less than 100 ppm if the outline of the black spot is visible (fig. 54).

- (2) Waters having low turbidities, such as the effluent from a purification unit, may be checked by adding about  $\frac{1}{2}$  inch of water to the cup and looking at the black spot. If, after filling the cup and again looking at the spot, it appears as black as it was originally, the turbidity is less than 5 ppm. Turbidities over 5 ppm produce a gray-ing or milky hue in the black spot.

*c. Turbidity Determination With Turbidimeter.* In using the turbidimeter, various bottles of water are prepared, to be used as standards of comparison. The first is 0-standard or turbidity-free water; the others are prepared with the standard stock solution, using the 0-standard water as a base.

- (1) *Preparation of turbidity-free water.* The 0-standard water is prepared as follows:

- (a) Fill two square 8-ounce bottles with clear drinking water.
- (b) Add a piece of filter paper which has been torn into 10 to 15 small pieces to each bottle.
- (c) Shake each bottle intermittently for about 10 minutes. The filter paper will become fluffy and gelatinous.
- (d) Add 1 ml of alum solution to each bottle and shake for 5 minutes.
- (e) Place a funnel and filter paper in two clean round bottles in the turbidimeter.
- (f) Filter about one-fourth of each bottle, remove the funnel, rinse the bottles with the filtered water, and discard the water. Replace the funnel and continue filtering until each bottle is full to the neck. Seal the bottles immediately with the screw cap to keep the samples dust-free and with a wax pencil, mark the bottles "0".

- (2) *Preparation of 3-ppm turbidity standard.* Thoroughly shake the standard turbidity solution in the stock solution bottle and immediately withdraw 3 ml of the solution and add it to the second bottle of turbidity-free water prepared in (1) above. Not more than 1 minute should elapse between shaking the solution and withdrawing the 3 ml for use. Then mark the bottle to which the solution was added with a "3", using the wax pencil.

- (3) *Preparation of other turbidity standards.* The operator unfamiliar with the use of the turbidimeter should prepare practice standards of 1 ppm and 10 ppm by adding 1 ml and 10 ml of stock solution respectively, instead of the 3 ml. He should then compare various combinations of the standards in the turbidimeter. New turbidity

standards should be prepared weekly because low turbidity standards keep only a short time. At least four standards would be used for comparison with water samples under ideal conditions. However, two standards, the 0-ppm and the 3-ppm, are used for routine readings because of the limited amount of stock turbidity solution and the number of bottles available. The 3-ppm standard is considered the most useful when only one standard can be prepared.

- (4) *Test procedure.* Place the standard and the sample of water to be compared in the turbidimeter next to the light opening (fig. 54). Remove the other bottles from the turbidimeter when making comparisons. Wipe each bottle clean before placing it in the turbidimeter. When viewing the bottles through the port in the back of the box and looking toward the sun, the suspended particles will sparkle and the sun's rays will be clearly visible. Under cloudy skies, the suspended particles will give the water a milky white color. For night or indoor comparisons, the flashlight and holder may be used. Water having no turbidity will not show the light rays or milky color. In making routine tests the 0-standard solution and the water sample are compared to give the observer the contrast between water with and without turbidity. The 0-standard is then replaced by the 3-ppm standard and the turbidity of the sample recorded as less than, equal to, or greater than 3 ppm. Other standards may be compared in the same way.

## 85. pH Determination

The pH determination and residual chlorine tests are both made with the color comparator. The pH value influences the amounts of chemicals used for coagulation (for instance, when the batch method of water treatment is being used, the pH value is determined and an "optimum pH" for best flocculation is arrived at) and for disinfection (for instance, chlorine is much more effective at a low pH than at a high).

*a. Determination by Use of Comparator.* Three indicator solutions are supplied for making pH determinations with the comparator. Bromcresol purple green is used for the pH range from 4.4 to 6.0 Bromthymol blue is used for pH values from 6.0 to 7.6 and cresol red-thymol blue is used for pH values from 7.6 to 9.2. Standard color disks covering each range are supplied with the indicator. Generally the bromthymol blue indicator is used first since most pH values fall within its range. The readings for pH are made immediately after adding the indicator. It should be kept

in mind that colorimetric indicators provide sharp changes in readings over a short span of the pH range, but once the end of this range has been reached, little change in color is noted even though a considerable change in pH takes place. For this reason, readings of 5.8 to 6.0 obtained when using the bromcresol purple green indicator, should be checked by taking a reading with bromthymol blue. Similarly, pH readings of 7.6 to 7.8 on the cresol red-thymol blue disk should be checked on the bromthymol blue disk.

*b. Emergency Procedure for Checking Approximate pH Value.*

If a color comparator is not available, methyl orange and phenolphthalein indicators may be used to make an approximate pH determination. These indicators, provided in the field water quality control Set No. 1, primarily for alkalinity determinations, are used as follows for a rough check of pH values:

- (1) To determine a low pH which is around 4.3, fill a test bottle to the 50-ml mark with a sample of the water to be tested and add 2 drops of methyl orange indicator. Observe test bottle against a white background, and interpret the color thus: pinkish red, pH below 4.3; yellow, pH above 4.3.
- (2) To determine high pH which is around 8.3, fill a test bottle to the 50-ml mark with a sample of the water to be tested and add 2 drops of phenolphthalein indicator. Observe test bottle against a white background, and interpret thus: pink, pH above 8.3; colorless, pH below 8.3.

## **86. Residual Chlorine Test**

The residual chlorine test is made to determine the quantity of available chlorine remaining in the water after satisfaction of the chlorine demand and disinfection has occurred.

*a.* Orthotolidine is the solution used in making the residual chlorine determination. This solution reacts with the residual chlorine, taking on a color which is matched against a standard color in the comparator disk. Readings up to 5 ppm may be read directly from the color disk (fig. 55).

*b.* The time required for full development of color by orthotolidine depends upon temperature, and the kind of residual chlorine present. Color develops several times faster when water is at 70° F. than when it is near the freezing point. For this reason, warm up cold samples quickly after mixing with orthotolidine. This may be done simply by holding the sample tube in the closed hand. For samples containing only free available chlorine, maximum color appears almost instantly and begins to fade after 1 minute. Take the reading at maximum color intensity. However, a



Placing indicator solution (orthotolidine) in test tube, preparatory to making residual chlorine test.



Holding test tube in palm of hand to insure that contents of tube will be above 50 degrees F., as required in residual chlorine test.



Reading the residual-chlorine amount on the color disk, after allowing a full 5-minute period for complete color development. A residual chlorine reading of at least 2.0 is required at the water point.

*Figure 55. Use of color comparator to determine residual chlorine.*

longer period is required for full color development of the chloramines which may be present, formed either by natural processes or by the presence of certain chemicals, as explained in paragraph 78. Since samples containing combined chlorine develop their

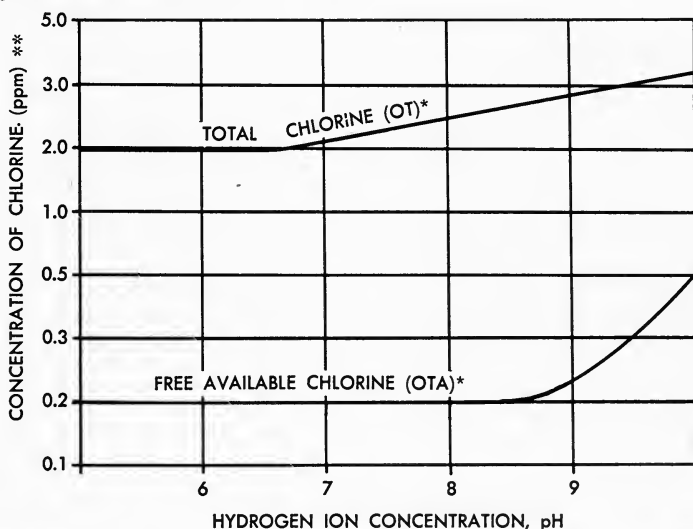


color at a rate primarily dependent on temperature and to a lesser extent on the quantity of nitrogenous material present, observe the samples frequently and use the maximum value. At 70° F., the maximum color develops in about 3 minutes, while at 32° F. it requires 6 minutes. The maximum color starts to fade after about 1½ minutes. Therefore in the OTA<sup>1</sup> test, the water temperature should be about 70° F. and the sample read at maximum color and in less than 5 minutes. Preferably, permit the color to develop in the dark. Read the sample frequently to assure observation of maximum color.

c. Use enough chlorine so that the residual in the finished water after 30 minutes of contact will be at least the amount indicated in the curve entitled "Total Chlorine (OT)" in figure 56, in accordance with the pH value of the water being treated. These residuals are effective for water temperatures ranging from 32° to 77° F. Bactericidal efficiency of chlorine increases with increase of water temperature.

d. Two types of residual chlorine have been mentioned as im-

<sup>1</sup> The terms "OT" and "OTA" refer to the concentration of active chlorine measured by the orthotolidine test and orthotolidine-arsenite test described in the 10th edition of *Standard Methods For the Examination of Water, Sewage and Industrial Wastes*.



\* The terms 'OT' and 'OTA' refer to the concentration of active chlorine measured by the orthotolidine test and orthotolidine-arsenite test described in the tenth edition of *Standard Methods For the Examination of Water, Sewage and Industrial Wastes*.

\*\* These residuals are effective for water temperature ranging from 32° to 77° F. Bactericidal efficiency of chlorine increases with increases of water temperature.

Figure 56. Minimum residual chlorine requirements, in accordance with hydrogen ion concentration (pH value).

portant. The first is the free available chlorine which can be measured by the OTA test (see lower curve, fig. 56), and which is valuable because it kills bacteria quickly. The second is the combined available chlorine, produced by the chloramines, a slower acting type and therefore one which requires a higher concentration to achieve an equivalent bactericidal effect in the same contact time.

e. The orthotolidine-arsenite (OTA) test is the preferable test to use in determining chlorine residuals since it permits the measurement of the relative amounts of free available chlorine, combined available chlorine, and color due to interfering substances. This test is best performed in a laboratory because the accuracy of the results is dependent not only upon the quantity of combined available chlorine present, but also upon the adherence to time intervals between the addition of reagents, and the temperature of the sample. With water temperatures above 68° F. the accuracy decreases, while below it increases. Currently this test cannot be performed by water point operators since they are not trained in the procedures and OTA test sets are not available to them. Army Medical Service personnel have such sets and currently perform the OTA test.

f. The free available chlorine residual subtracted from the total residual chlorine would equal the combined available residual. As stated above, the combined available residual is actually that slower-acting residual created by the chloramines which have formed in the water. Since the OT test measures only the total available chlorine residual, it is impossible to determine the combined available chlorine residual with this test. With the orthotolidine test both the free and combined available chlorine are measured. If it is desired to determine whether the residual is present in either the free or combined form, it is necessary to employ the orthotolidine-arsenite test. In disinfection of field water supplies it is always preferable to be able to have the chlorine in the form of free available chlorine and to have the water at as low a pH as possible and still permit effective coagulation. Reliance upon combined available chlorine increases the contact time or dosage required if contact time remains constant.

## 87. Chlorine Demand Test

a. *Nature of Test.* A discussion of chlorine demand is given in paragraph 78e(3). The chlorine demand test is used as a guide in determining how much chlorine is needed to treat a given water. Briefly, the test consists of: preparing a measured test dosage of chlorine, adding it to a sample of the water to be treated, and reading the resultant residual after 30 minutes' contact time. Re-

quired dosage is then computed; it is the chlorine needed to equal the sum of the demand plus the minimum required residual.

*b. Test Procedure.* A commercially available compound, calcium hypochlorite, containing 70 percent available chlorine, is used for the test.

- (1) Mix 7.14 grams of calcium hypochlorite ( $\text{Ca}(\text{OCl})_2$ ) with 1,000 cc of the best water available to produce 5,000-ppm chlorine solution. (Details of how the quantity of 7.14 grams is arrived at, and the procedure for making the test solution, are set forth in appendix V.) One milliliter of this standard solution, hereafter referred to as the reagent, when added to 1,000 cc of the water to be tested, equals 5 ppm chlorine test dosage. Thus, with 1 milliliter of the reagent equalling 5 ppm, any proportionate test dosage may be arrived at by using one-fifth, or 0.2 ml, of the reagent in 1,000 cc of the water for each ppm of chlorine dosage desired.
- (2) Add a test dosage of a known strength to a 1,000 cc sample of the water to be tested (5 ppm, or 1 ml, of the reagent is normally used).
- (3) Wait 30 minutes and run a chlorine residual test.
- (4) Subtract this residual from the test dosage to obtain the chlorine demand.
- (5) If a residual is not obtained after a 30 minute period, the test is invalid and must be repeated, by increasing the reagent by 5 ppm each time, until a residual is obtained.

If, for example, the test were repeated three times, the results would be recorded as follows:

Test dosage, $3 \times 5 =$	15.0 ppm $\text{Cl}_2$
$\text{Cl}_2$ Residual	$= -5.0 \text{ ppm } \text{Cl}_2$
$\text{Cl}_2$ Demand	$= 10.0 \text{ ppm } \text{Cl}_2$

Formulas for computing quantities of calcium hypochlorite to be added to a given container of water, after the chlorine demand has been established, are given in paragraphs 72 through 75.

### 88. Coagulation Test

*a. Optimum pH.* The optimum pH, the pH value which gives the best flocculation and sedimentation, varies considerably with the water being treated. Optimum conditions may differ from day to day, and even during one day, because of changes in the quality of the water. The coagulation test is not used when continuous flow equipment is used.

*b. pH Curves.* The pH curves shown in figures 57 and 58 illus-

trate graphically the importance of knowing the optimum pH value of the water to be treated. Figure 57 shows a broad curve obtained for Potomac River water. This type of curve indicates that the water is easy to treat because a good floc can be obtained over a considerable range of pH values. The curve for Accotink Creek (fig. 58) indicates that a precise adjustment must be made to obtain the optimum pH.

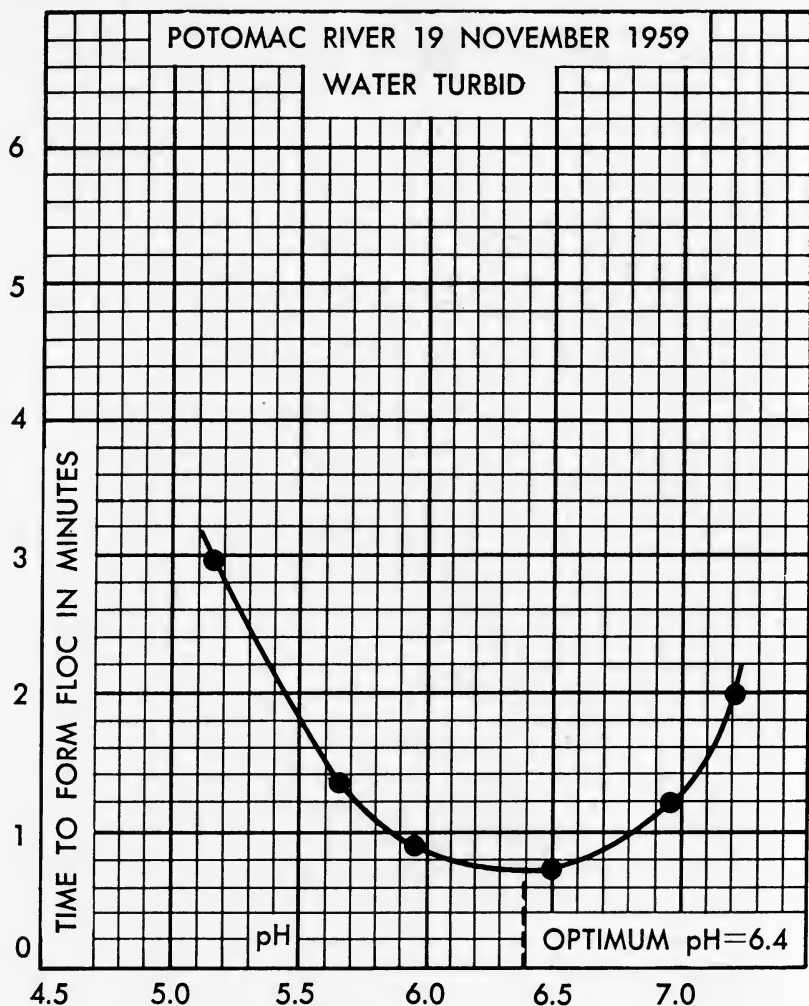


Figure 57. pH curve—Potomac River water.

c. Preparation of Standard Solution Using Alum and Soda Ash.

- (1) Alum. Remove the graduated dropper from the 4-ounce alum bottle in the right hand reagent drawer of the quality control set (fig. 47) and insert the funnel into

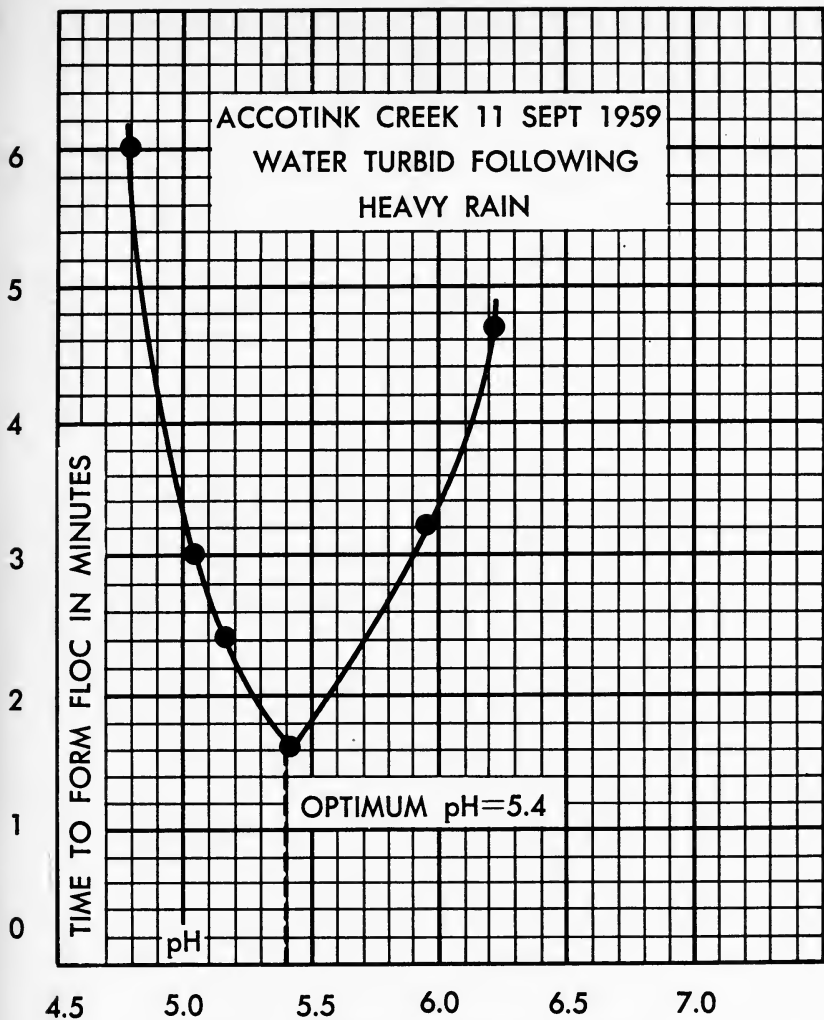


Figure 58. pH curve—Accotink Creek water.

the empty bottle. Place clear potable water in an empty bottle from the chest. Carefully open an alum capsule directly over the funnel so that there will be no chemical lost. Use the water which was earlier placed in the bottle to wash the alum from the capsule and the funnel into the alum bottle. Replace graduated dropper, and shake solution until all the chemical is dissolved. Before preparing a refill alum solution, discard any small portion of old solution remaining and rinse the bottle.

- (2) *Soda ash.* The soda ash solution is prepared in exactly the same manner, using a soda ash capsule and bottle. A drop or two of phenolphthalein solution is normally

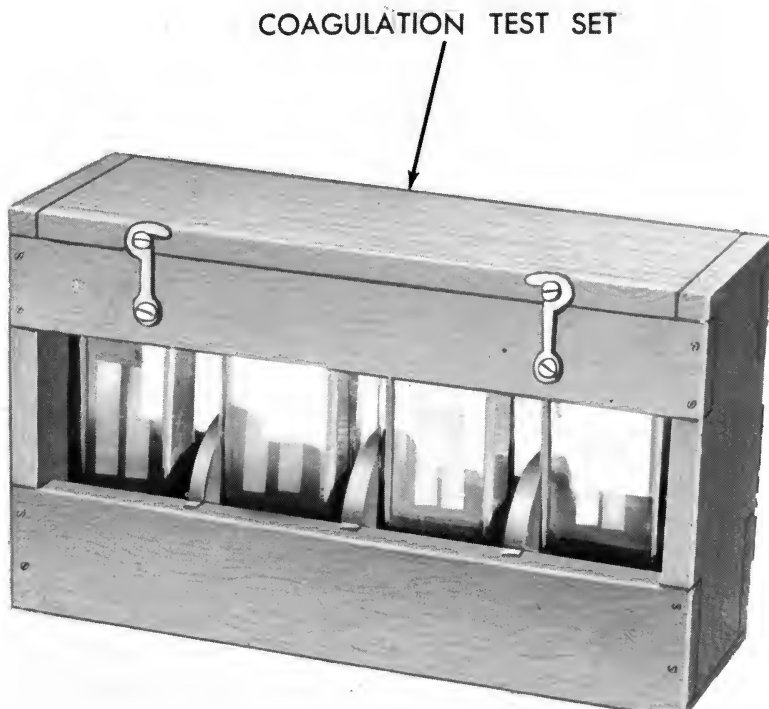
added to each bottle. The pink coloration formed at a high pH provides an easy method of distinguishing between the two solutions.

*d. Test Procedure.*

- (1) In making the coagulation test, fill the bottles of the test set (fig. 59) with the raw water to be treated. Add alum and soda ash solutions to each of the bottles in dosages as shown below. This is considered the basic scheme, but may be varied according to the raw pH. This test is based on trial and error, and the scheme may speed up adjustment during successive trials until a good floc is obtained.

	Bottle No.			
Chemical .....	1	2	3	4
Alum (in gpg) .....	4	6	8	10
Soda ash (in gpg) .....	2	3	4	5

The dosages are added by using the calibrated dropper. It delivers a dose of 1 gpg (grains per gallon) in 8 ounces of water when filled to the lower mark, and 2 gpg when filled to the upper mark. When  $\frac{1}{2}$ -gpg dosages are required, it is necessary to estimate the midpoint between marks.



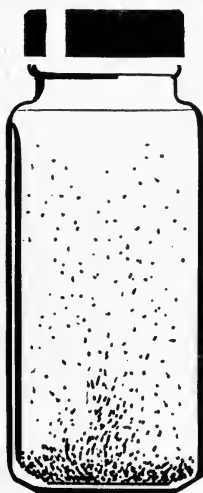
*Figure 59. Coagulation test set.*

BOTH TESTS START  
WITH RAW WATER



RAW WATER  
TIME: 0000

NO COAGULANT ADDED



SAME WATER  
TIME: 0020

COAGULANTS  
(ALUM & SODA ASH) ADDED



SAME WATER  
TIME: 0020

*Figure 60. Jar test—showing formation of floc.*

- (2) After adding the alum and soda-ash to the water, place the bottles in the holder and shake vigorously for several seconds, then gently agitate for 2 minutes or until the floc begins to form (fig. 60).
- (3) Hold the coagulation test set in the shade and observe the formation of the floc against the light. If a satisfactory floc has formed, determine the pH of the sample. A satisfactory floc is one which has attracted suspended particles and settled, leaving the water above the floc clear. The floc must form and be visible to the naked eye within 2 minutes.
- (4) Determine the pH of the water in the sample bottle which gives the best floc. If several dosages give good floc, the one with the lower dosages is generally selected to save chemicals. This pH and the corresponding alum and soda-ash dosage are considered to be optimum for flocculation. A settling time of 15 minutes should be used in this test.

*e. Preparation of Expedient Alum Solution.* When capsules are not available, the alum and soda ash solutions may be made by the use of expedient procedures. The same testing routine is then followed as when capsules are used. Following is the procedure for preparing the expedient alum solution:

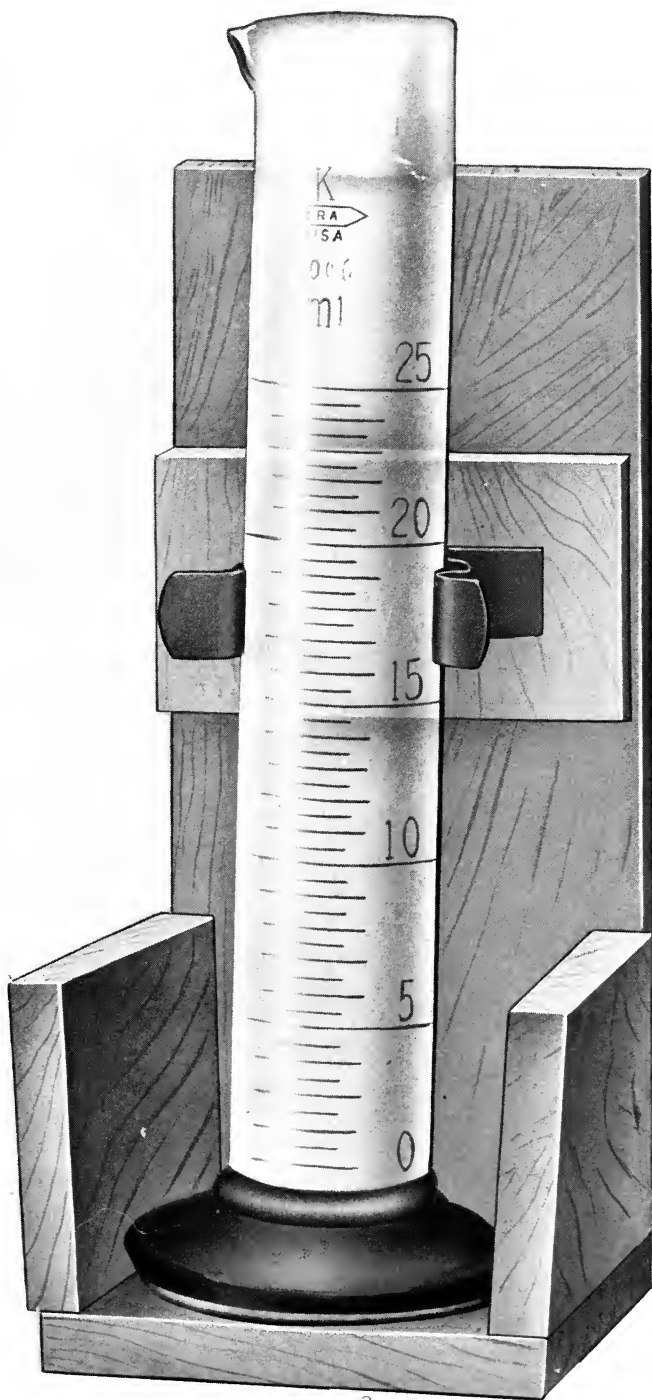
- (1) Place 10 ml of the best water available in the 25-ml graduate (fig. 61).
- (2) Crush standard lump alum into a fine powder. Carefully add this powder to the graduate until the water level reaches 12.5-ml mark.
- (3) Pour this into the 32-ounce measuring cup and add best water available to make up 16 ounces of solution.
- (4) One ml of this solution per 8 ounces of water to be tested equals 2 grains per gallon.

*f. Measurement of Chunk Alum in Field.* Chunk alum can be measured by using the measuring cup (fig. 62). Bring the water level to the 16-ounce mark in the cup. Carefully add chunks of alum until the level of water rises to the 24.5-ounce mark. This will be a 2-grain-per-gallon dosage of alum; and this ratio will always be constant. Alum dosages and corresponding water levels are listed in appendix II, table IX.

*g. Preparation of Expedient Soda Ash solution.* Following is the procedure for preparing the expedient soda ash solution when capsules are not available:

- (1) Collect 10 ml of best water available in 25-ml graduate.
- (2) Crush standard soda ash briquette into a fine powder and add this powder to the graduate until the water reaches the 12-ml mark.





*Figure 61. 25-milliliter graduate and holder.*

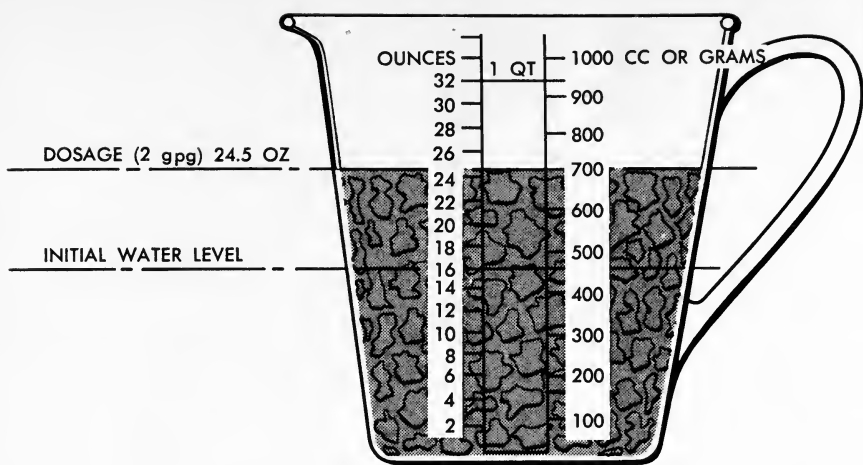


Figure 62. Measuring 2 gpg dosage of alum.

- (3) Empty this solution into the measuring cup and add 18 ounces of the best water available. Add 2 drops phenolphthalein solution as identifying color.
- (4) One ml of this solution per 8 ounces of water to be tested equals 2 grains per gallon.

## 89. Salinity Tests

*a. Types of Tests.* The following four salinity tests are performed with the water quality control set. The results of the four tests are used to calculate the approximate total dissolved solids in the water.

- (1) *Soap hardness test.* Used as a measure of total hardness. The presence of calcium and magnesium salts, and to a lesser degree certain other dissolved minerals, constitutes hardness in water, which causes scale in boilers and vehicle radiators.
- (2) *Alkalinity test.* Measures the amount of carbonates, bicarbonates, and hydroxides in the water. It is desirable to know the alkaline content of water which is to come in contact with metals at high temperatures.
- (3) *Chloride test.* Measures concentration of chloride ions in the water, which indicates the presence of possible sewage pollution.
- (4) *Sulfate test.* Used to determine whether sulfates are present in sufficient quantities to cause undesirable physiological effects (sulfates can cause diarrhea in human beings). Although waters with higher sulfate

content have been consumed without adverse effects, TB MED 229 recommends 250 ppm as the permissible limit.

*b. Calculating Total Dissolved Solids.* Each of the four salinity tests serves to identify mineral characteristics of the water. An approximation of the total dissolved solids may be made by combining the test results as follows:

Total dissolved solids (ppm) = (ppm alkalinity) + (ppm sulfates  $\times$  1.4) + (ppm chlorides  $\times$  1.6)

*Example:* Salinity test of water

Alkalinity = 200 ppm

Sulfates = 100 ppm

Chlorides = 300 ppm

Total dissolved solids =  $200 + (100 \times 1.4) + (300 \times 1.6) = 200 + 140 + 480 = 820$  ppm

*c. General Procedure for Salinity Tests.* Two bottles of reagents, one small and one large, are provided for each test. The small bottle is filled, as required, from the large bottle. The test bottles have two marks, the lower at 50-ml capacity and the upper at 100-ml capacity. The test solutions are measured with 1 ml pipettes which are calibrated in 1/10 ml divisions. Each pipette is used only for the test for which it is marked in the pipette case and is returned directly to its place when the test is completed. The pipette is conveniently manipulated by placing it in the palm of the hand with the rubber bulb between the thumb and forefinger.

## 90. Soap Hardness Test

*a.* Fill the hardness-testing bottle to the 50-ml mark with the water sample to be tested. Add soap solution to the water, 1/2 ml at a time, with the soap pipette. Shake the bottle vigorously after each application and place it on its side on a fixed surface. If no lather forms, continue adding 1/2 ml portion of soap solution at a time and place the bottle on its side each time. As soon as a lather appears, allow the test bottle to remain undisturbed on its side until the surface of the lather breaks and plainly shows the water through the opening in the lather film. The lather disappears more slowly after each addition of soap solution. When the lather does not break within 5 minutes, it is considered a permanent lather and the test is completed. Determine the hardness in ppm as follows:

Hardness (ppm) =  $50 \times$  (total number of ml of soap solution required for permanent lather).

*b.* If a permanent lather does not appear after application of 6 ml of soap solution, repeat the test with a new water sample which has been diluted with an equal quantity of zero-hardness water. First, measure 25 ml of the water sample in the graduated cylin-

der and transfer it into the hardness-testing bottle. Next, carefully pour 25 ml of zero-hardness water into the cylinder from the top of the bottle to avoid losing any of the solid material. Add the zero-hardness water to the water in the testing bottle and perform the test as outlined in *a* above. When a permanent lather has been obtained, calculate the hardness as follows:

$$\text{Hardness (ppm)} = 100 \times (\text{total number of ml of soap solution required for permanent lather}).$$

c. None of the zero-hardness water should be wasted. Additional zero-hardness water can be prepared to complete the test by refilling the bottle containing the zero-hardness water with clear drinking water and shaking it mildly for 10 minutes before using. The ion exchange resin in the bottle is capable of softening very hard waters. It will be effective on approximately forty 25-ml portions before becoming exhausted. Its life may be prolonged by refilling the bottle with relatively soft water. A simple check for zero-hardness water is obtained by adding  $\frac{1}{2}$  ml of soap solution to 25 ml of the water in the hardness testing bottle. If a 5-minute lather is not obtained, the chemical is considered exhausted.

d. The presence of an appreciable amount of magnesium in water sometimes causes a false end point. To prove that an end point is not false, add  $\frac{1}{2}$  ml of soap solution after the first permanent lather is obtained. If the lather breaks up within the 5-minute period, the end point was false because of the presence of magnesium. Add soap solution until a permanent lather is again obtained. The total amount of soap required to obtain the final end point is used in calculating the hardness.

e. Water having no hardness (distilled water) requires a very small amount of soap to produce a lather. The amount of soap required to produce a lather is known as the lather factor and varies with the type of soap used. The lather factor normally appears on the label of the soap reagent bottle. The lather factor of the soap solution used in the test set should not exceed a few tenths of a milliliter. To obtain the correct hardness of the water, the milliliters of lather factor should be subtracted from the total milliliters of soap used before making the calculation for hardness.

## 91. Alkalinity Test

The alkalinity of water may be the total or methyl orange (MO) alkalinity, or the phenolphthalein alkalinity. Few surface or ground waters show phenolphthalein alkalinity. Nearly all waters, except those which are acid, show MO alkalinity.

### a. Methyl-Orange Alkalinity.

- (1) Fill the test bottle to the 50-ml mark with the water sample to be tested.

- (2) Add two drops of methyl orange indicator solution. Place the test bottle over a white towel or other white surface so a change in color of the solution can readily be seen.
- (3) Add sulfuric acid solution with the sulfuric acid pipette until the test sample begins to turn from yellow to pinkish red. Record the total number of ml of sulfuric acid solution used.
- (4) Calculate the MO alkalinity as follows:  

$$\text{MO alkalinity (ppm of } \text{CaCO}_3) = 100 \times \begin{matrix} \text{(total number} \\ \text{of ml of sul-} \\ \text{furic acid re-} \\ \text{quired)}. \end{matrix}$$

*b. Phenolphthalein Alkalinity.*

- (1) Fill the test bottle to the 50-ml mark with the water sample to be tested.
- (2) Add two drops of phenolphthalein-indicator solution. Place over a white surface as in the MO test. If no color appears in the sample, record the value of phenolphthalein alkalinity as zero.
- (3) If a pink color forms in solution, test the sample by adding sulfuric acid solution a drop at a time until the pink color just disappears. Record the total number of ml of sulfuric acid used.
- (4) Calculate the phenolphthalein alkalinity as follows:  

$$\text{Phenolphthalein alkalinity (ppm of } \text{CaCO}_3) = 100 \times \begin{matrix} \text{(total number} \\ \text{of ml of} \\ \text{sulfuric} \\ \text{acid re-} \\ \text{quired)}. \end{matrix}$$

## 92. Test for Chlorides

- a.* Fill a test bottle with 50 ml of the water sample to be tested.
- b.* Add three drops of potassium chromate (yellow) indicator solution.
- c.* Add silver nitrate solution with the silver nitrate pipette, *a drop at a time*, until the water sample begins to change from a yellow to a definite reddish color. After each addition of silver nitrate solution, mildly agitate the water sample by rotating the bottle back and forth. Record the total number of ml of silver nitrate required to change the water color.
- d.* Calculate the chlorides in terms of the chloride radical (Cl) as follows:  

$$\text{Chlorides (ppm)} = 100 \times \begin{matrix} \text{(total number of ml of silver ni-} \\ \text{trate required)}. \end{matrix}$$

### 93. Test for Sulfates

*a.* The sulfate test often requires several trials and gives only approximate values.

*b.* The test is begun by testing for sulfates at 100 ppm as follows:

- (1) Fill a clean test bottle to the 100-ml mark with the water sample.
- (2) Add 1 ml of barium-chloride solution with the barium-chloride pipette to the sample. Shake intermittently for 10 minutes.
- (3) Tear a piece of filter paper into small pieces and place the pieces in the solution.
- (4) Shake the bottle for 5 minutes or until the paper becomes fluffy and gelatinous.
- (5) Place a funnel and filter paper in a second bottle. Fold the filter paper as shown in the instruction book.
- (6) Filter about 25 ml of the sample into the second bottle. Rinse the second bottle with this amount of filtrate, and then discard the filtrate. Replace the funnel and continue filtration until 50 ml of filtrate are collected.
- (7) Add 1 ml of barium-chloride solution to the filtrate with the barium-chloride pipette. Shake for 5 seconds, and observe immediately for a precipitate or clear solution.

*c.* If a clear solution is obtained, record the sulfates as less than 100 ppm. An immediate precipitate or milky solution indicates the sulfates are greater than 100 ppm and a new sample must be tested for 200-ppm sulfate. This test is performed as in *b* above, except that in (2), 2 ml of barium chloride solution are added. For each additional 100-ppm sulfate test required, add 1 ml of barium-chloride solution. Therefore, 3 ml of barium-chloride solution must be added to test for 300-ppm sulfate. However, the 1 ml of barium-chloride solution added after filtration is not changed.

*d.* If a clear solution is obtained, the sulfates are less than the ppm for which they were tested, and the value is recorded as between the values of the last preceding tests. A precipitate or milky solution requires that a new sample of the water be tested for the next higher value.

## Section V. CONTINUOUS FLOW AND BATCH TREATMENT PROCESSES

### 94. Basic Features of Continuous Flow Equipment

*a.* The continuous flow type equipment is designed for continuous purification of natural raw water by the suspended solids

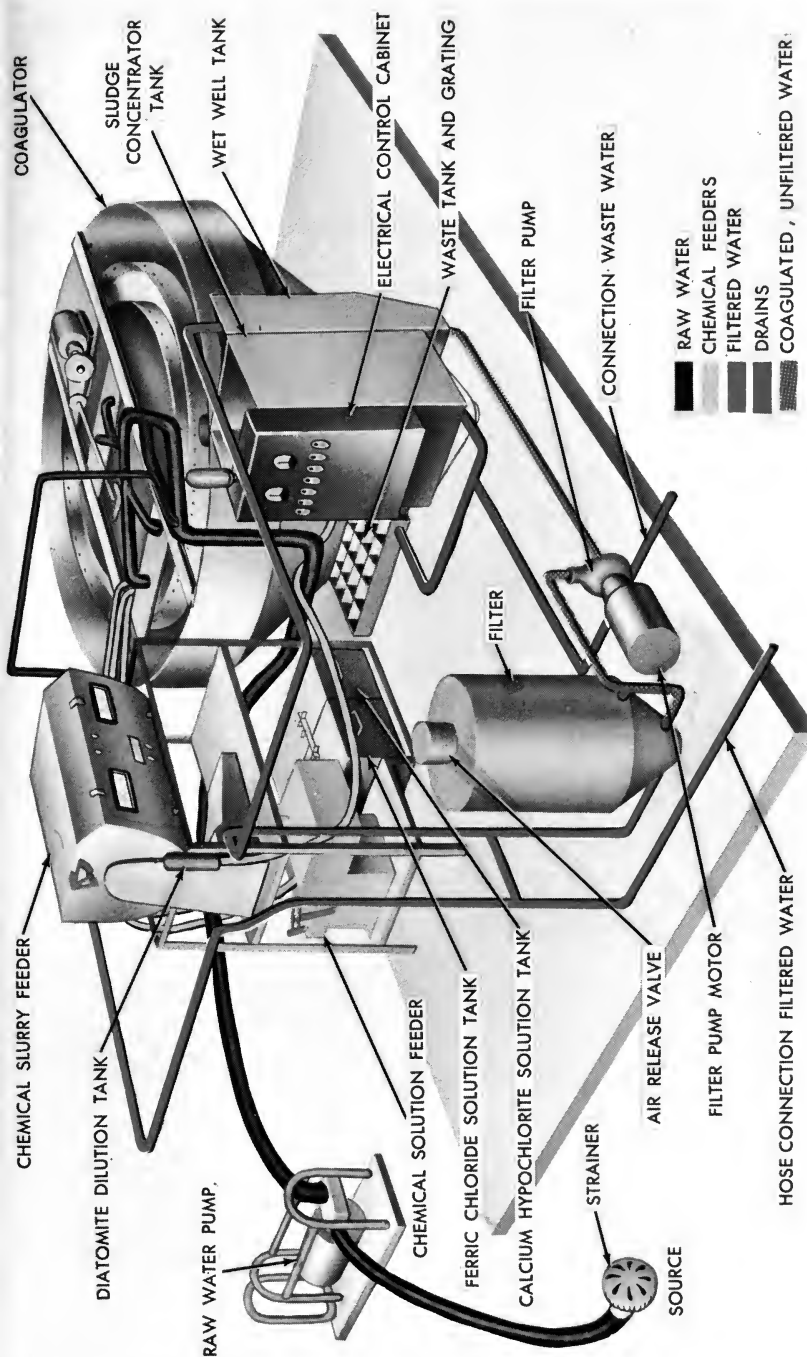


Figure 63. Continuous flow type equipment.

contact method of water treatment. If no better source can be found, continuous flow equipment can be operated to produce water from polluted streams. Water enters, is treated, and leaves the equipment at a constant rate of flow, 24 hours a day if necessary; thus its operation is called "continuous flow." Standard models of the equipment are discussed in paragraph 38.

b. All models contain—

- (1) A continuous flow solids-contact clarifier for coagulating water.
- (2) An external sludge concentrator connected to the solids-contact clarifier for continuous withdrawal of suspended slurry.
- (3) A holding tank (wet well) for the collection of the chemically treated and coagulated water.
- (4) Ferric chloride, limestone, and hypochlorite feeders for chemical treatment of the raw or decontaminated water.
- (5) A filter pump (or pumps) for pumping coagulated water at a constant rate through the filter (or filters).
- (6) A pressure type diatomite filter or filters.
- (7) A diatomite slurry feeder for constant dosing of filter influent water with diatomaceous silica.
- (8) Necessary piping assemblies, electrical systems, and appurtenances for continuous operation of the unit as a complete water purification unit.

c. All models are designed for the interchangeability of parts where possible. Figure 63 shows the general layout and nomenclature of the equipment.

## 95. Coagulator Assembly

The coagulator assembly (fig. 64) includes the coagulator, influent and effluent launders, agitator shaft with circular disks, sludge concentrator tank, and wet well tank. The coagulator assembly reduces the organic and suspended matter content of the water and produces an effluent suitable for application to the filter unit.

## 96. Operation of Coagulator Assembly

a. Raw water is pumped directly from the source into the coagulator assembly (fig. 64). It is introduced at the top of the coagulator into the influent launders through the aspirators, which aerate the raw water. The water overflows from the influent launders into the mixing zone, where chemicals are added: ferric chloride, pulverized limestone, and calcium hypochlorite. When activated carbon is needed for a special purpose, such as decontamination or removal of taste or odor, it is also added here.

b. As the water and chemicals descend through the mixing



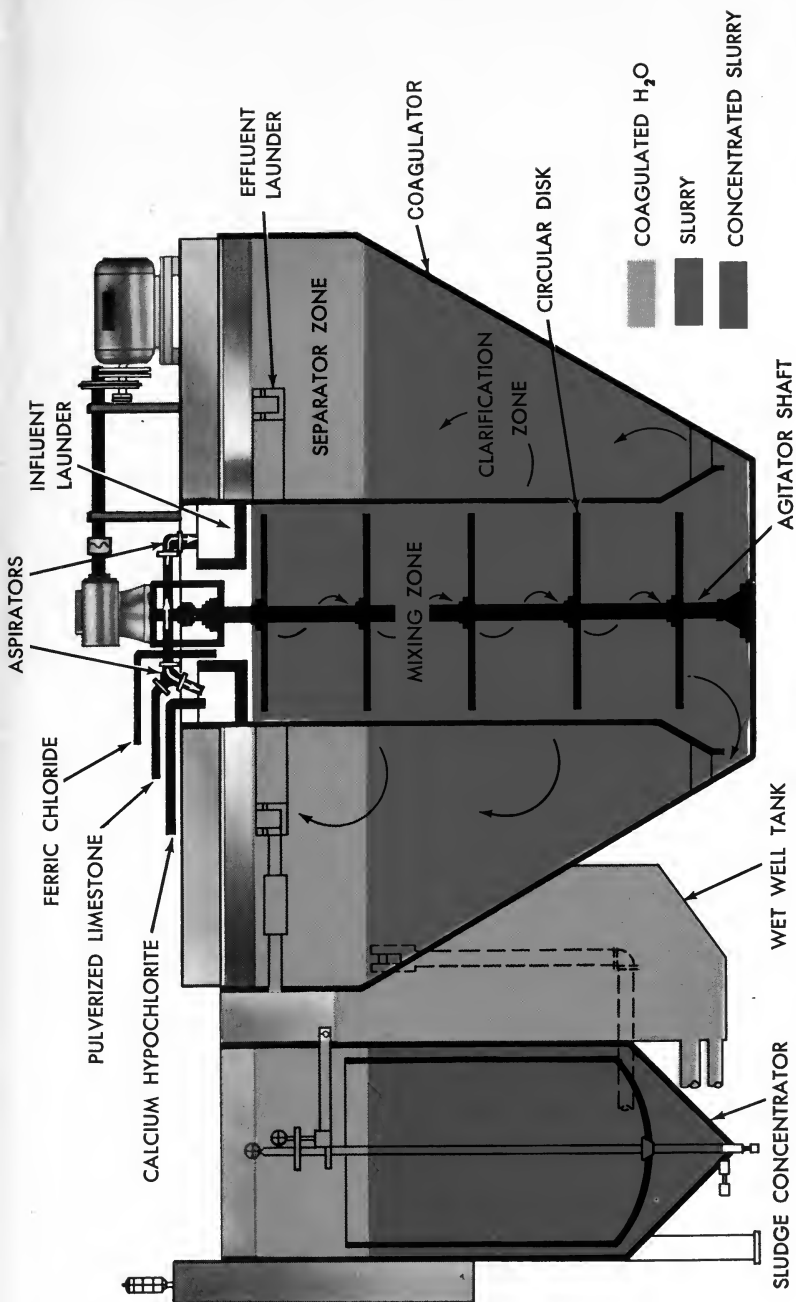


Figure 64. Coagulator assembly.

zone, they are thoroughly mixed by the motion of five flat circular disks located at equal intervals on the rotating agitator shaft, at the center of the coagulator. This flow is a downward rotation. At the bottom of the coagulator are shallow baffles which deflect the flow and start it in a counterrotation.

c. The baffles direct the water into the clarification zone, the slant-sided area which surrounds the mixing zone. It is forced upward in a counterrotation at a reduced speed but continues with sufficient velocity to keep the slurry volume, together with the clear water above the slurry pool, rotating. The coagulants draw the solids into increasingly large particles which, because of their weight, tend to rise more slowly than the clear water which goes to the top of the clarification zone. These actions which take place in the mixing zone and the clarification zone illustrate the terms "solids contact" and "upward flow," used to describe the continuous flow water purification units.

d. There is a distinct separation of the clear water in the separator zone and the slurry in the clarification zone. At the top of the separator zone, the clear water is collected by the effluent launder and is continuously drawn off and discharged into the "wet well" tank. There it is stored until it is delivered into the filter. Besides providing storage space for clarified water, the wet well tank also acts as a sump for the suction of the filter pump.

e. The sludge concentrator tank is attached externally to, and at one quadrant of, the coagulator. The sludge concentrator tank functions as a small auxiliary coagulator. It draws slurry, still in the flocculent stage, from the clarification zone, and provides a longer holding period for slurry concentration than does the clarification zone itself. The sludge concentrator tank also permits settling of sludge to the bottom of the tank for continuous or intermittent drainage to waste, and skimming of clear coagulated water at the top of the tank for return to the wet well. So far, the water has been subjected to the processes of coagulation, sedimentation, and chlorination, by one continuous flow process.

## 97. Operation of Filter Unit

a. *Method of Operation.* Further purification of the water is necessary. Remaining solids must be removed by filtration. The diatomite system causes the water to be forced through a layer of diatomaceous earth and serves to remove the remaining suspended impurities. Properly operated diatomite filters (fig. 65) are capable of removing from coagulated and settled water amebic cysts, the cercariae of schistosomes, and approximately 90 percent of the bacteria as well as producing water with less than one unit of turbidity.

b. *Filtration and Backwash Procedure* (fig. 66). A slurry of



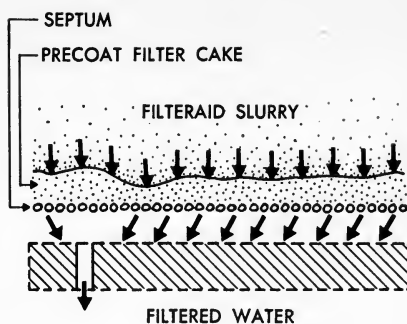
*Figure 65. Filter element disassembled, showing plastic cups and plastic cover rolled back.*

diatomite and water is introduced into the filter to precoat the system before the filter is put into operation. The diatomite is held and supported on the filter element (there are six filter elements inside a filter unit) by the flow of water into the filter unit. During the filtering process, the porosity of the filter cake is maintained by the continuous addition of a small amount of diatomite slurry. When the pressure required to pump water through the filter increases, it indicates that the filter is clogging, and backwashing is necessary. To do this, the air release valve is opened. The air pressure under the filter dome is thus suddenly released, allowing the air in the filter element air traps to expand with the effect of a blast which knocks the diatomite and foreign matter off the filter elements. This is called backwashing by the air bump method. After the filter has been backwashed and drained, the filter pump should then be used to flush the filter, before the unit is again precoatd and put back into operation.

## **98. Batch Treatment Procedure**

a. The batch treatment procedure consists essentially of the necessary tests, followed by coagulation and disinfection, usually in one simultaneous step, filtration, and then storage or distribution. Before the floc tank is filled, or (if a new water supply is being established) while the floc tank and raw water pump are being set up, the following tests are run:

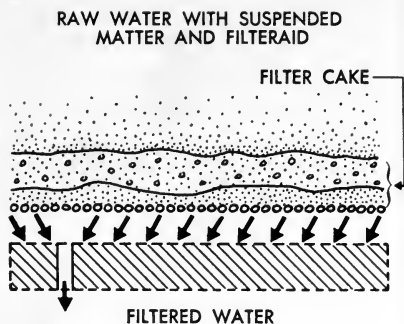
- (1) Turbidity test, using measuring cup with dot (par. 84).
- (2) Raw pH determination test (pars. 82, 83, and 85).



**1. CROSS SECTION VIEW**

**DURING PRECOATING**

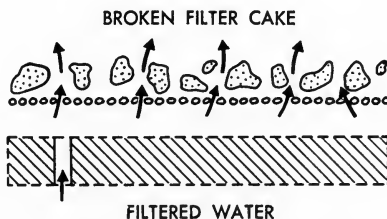
Flow of filteraid in suspension is greatest through thinnest portion of filter cake, building up that portion and resulting in uniform coating of filteraid over entire element.



**2. CROSS SECTION VIEW**

**DURING FILTERING**

Porosity of the filter cake is maintained under pressure by rigid particles of filteraid mixing with compressible particles of suspended matter in raw water.



**3. CROSS SECTION VIEW**

**DURING BACKWASHING**

In backwashing, filtered water drawn through septum dislodges and breaks filter cake; then discharges it from bottom of filter tank.

*Figure 66. Operation of filter element.*

- (3) Jar test for coagulation, by which optimum pH is established (par. 88).
- (4) Chlorine demand test (par. 87).

With these tests, the operator establishes the type and amount of chemical treatment needed by the raw water source that is to be used. Since the chemical nature of the water changes from day to day, these tests must be repeated frequently to insure that treatment is being kept appropriate to the chemical content of the water.

b. Having established the types and amounts of chemicals to be used, the operator now measures out the chemicals for the first tankful of raw water. Meantime other members of the water sup-

ply team fill the floc tank. The chemicals are placed in the wire baskets provided for this purpose and suspended high inside the coagulation tank. The raw water influent hose is directed toward the chemical baskets and along the inside of the tank. Rate of flow is kept high to facilitate dissolving of the chemicals (par. 76b); circular motion derived from direction of the flow causes agitation of the water. The agitation is necessary in order to cause the fine floc particles and the various impurities to coagulate into a denser material which will settle more easily.

c. The four salinity tests (par. 89) are now run, to learn the types and amounts of dissolved solids in the water and to deter-

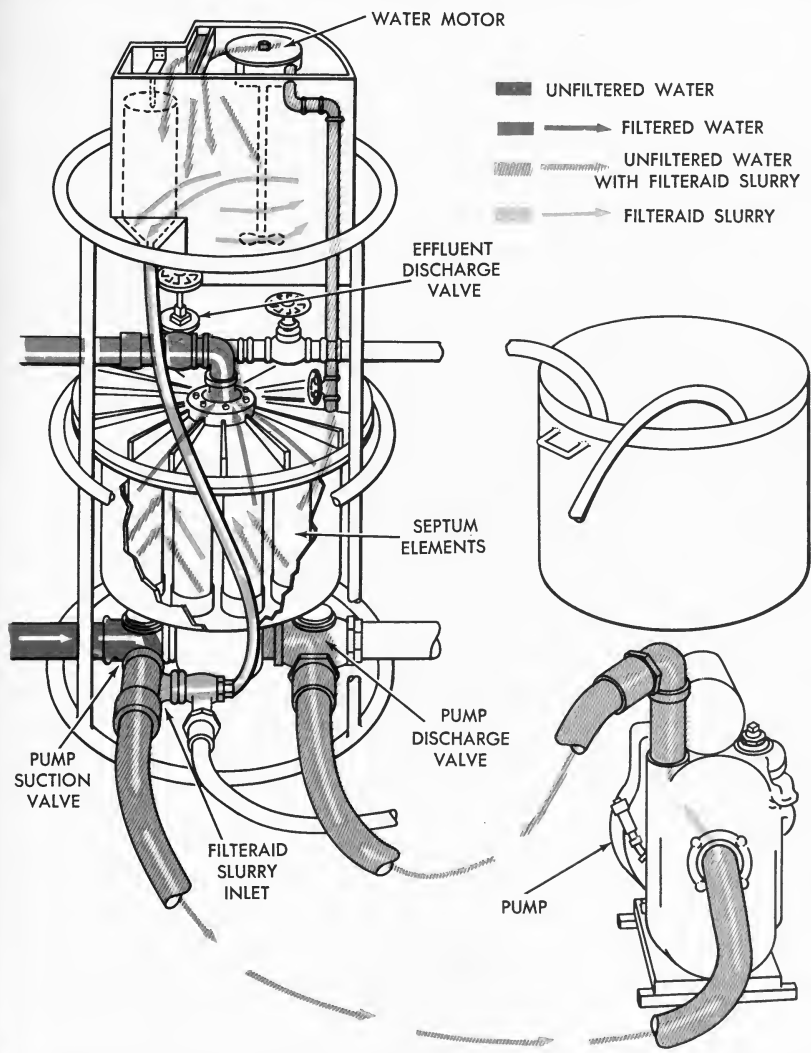


Figure 67. Flow diagram, production of filtered water in diatomite portable 50 gpm unit.

mine whether, and what, further treatment is necessary. If contamination or other special problems are revealed, this is the proper point in the batch treatment procedure to make arrangements to deal with them. If contamination is discovered, further tests with the screening kit (par. 117) may be necessary. Decontamination procedures for removal of chemical (and also biological and radiological) warfare agents and such accidental contaminants as may come from industrial wastes, are explained in paragraphs 106 through 108. If no contamination exists, but other special problems such as taste, odor, or extreme hardness of the water are revealed, the procedures described in paragraphs 109 through 115 must be followed.

d. The filter and its pump are next set up, and decontamination or other special procedures which must be included are incorporated into the cycle.

e. The operation of the diatomite filter which is a component of Sets 3 and 4 is similar but not identical to that of the continuous flow units (fig. 67). Briefly, the 35 gpm and 50 gpm diatomite filters operate as follows: a small amount of diatomite slurry is added, as necessary, at the appropriate intake on the filter; coagulated water is drawn in through the influent hose; the two, mixed, pass through the suction pump and are forced upward through the precoated septum elements, where the actual filtration takes place; the filtered water is drawn off through the effluent discharge hose.

f. Precoating must be accomplished before the filter is placed in operation (fig. 68). This is done by feeding a diatomite slurry into the filter while it is on precoat cycle. When filter production falls off due to clogging of the elements, the unit must be backwashed. The intake of coagulated water is stopped and all apparatus switched to backwash, which reverses the direction of flow. Filtered water is now drawn from the storage tank and forced "backward" through the filter unit, flushing out the used diatomite (fig. 69). This water must be wasted, of course. Backwashing is continued until the water runs clear from the waste hose. Next, a new precoat is applied before the unit is put back into filter operation.

g. The used diatomite filter substance can be reclaimed for further use by drying it thoroughly and then combining it, approximately nine parts used diatomite with one part new. However, this is done *only* when fresh diatomite is critically low in supply. A quantity of calcium hypochlorite solution must be used to decontaminate old diatomaceous earth when it is being reclaimed.

*Note.* Used diatomite cannot be reclaimed when CBR warfare agents are being treated in the water purification system.

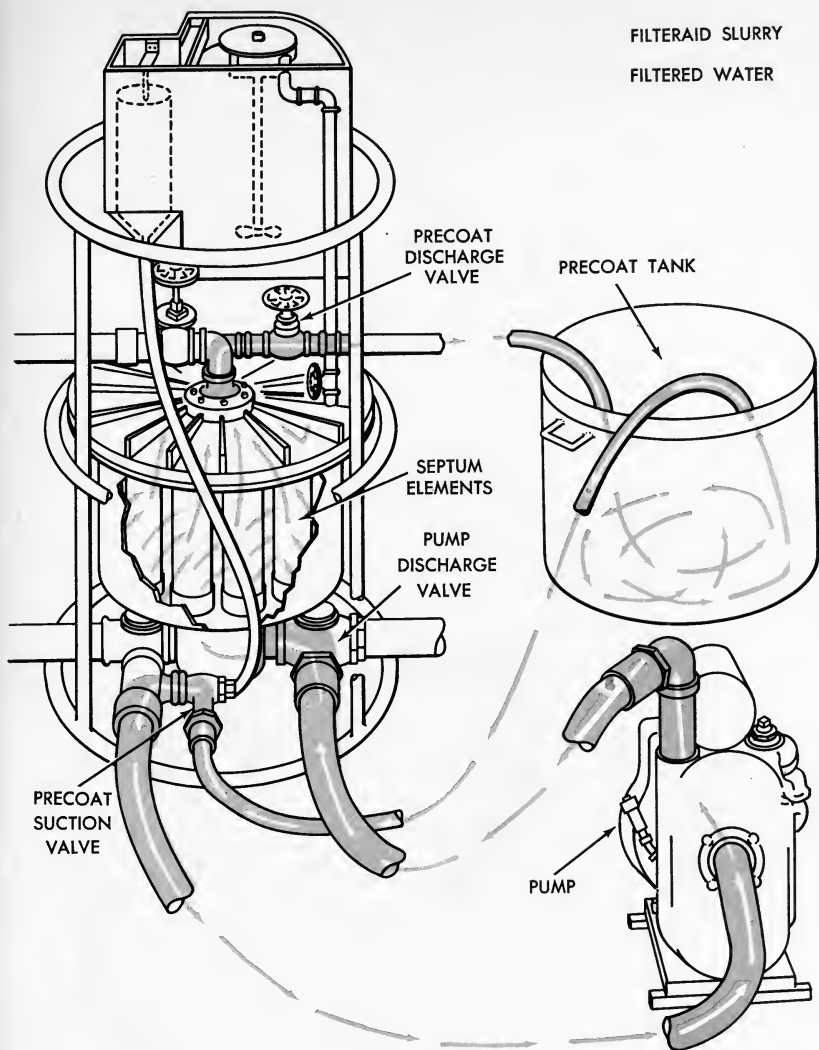


Figure 68. Flow diagram during precoating process in diatomite portable 50 gpm unit.

*h.* While the filter is being readied for operation, the clearwell and distribution pumps are set up and prepared for operation, and whatever additional coagulation tanks are to be used are now erected.

*i.* In this type of water treatment the coagulated water must be kept for relatively long periods of time before filtration. Two or more floc tanks or "batches" of water must be settling while still another tank of coagulated, settled water is being filtered. Multiple floc tanks are necessary to maintain capacity filter output. The term "batch treatment" is accordingly applied to this process.

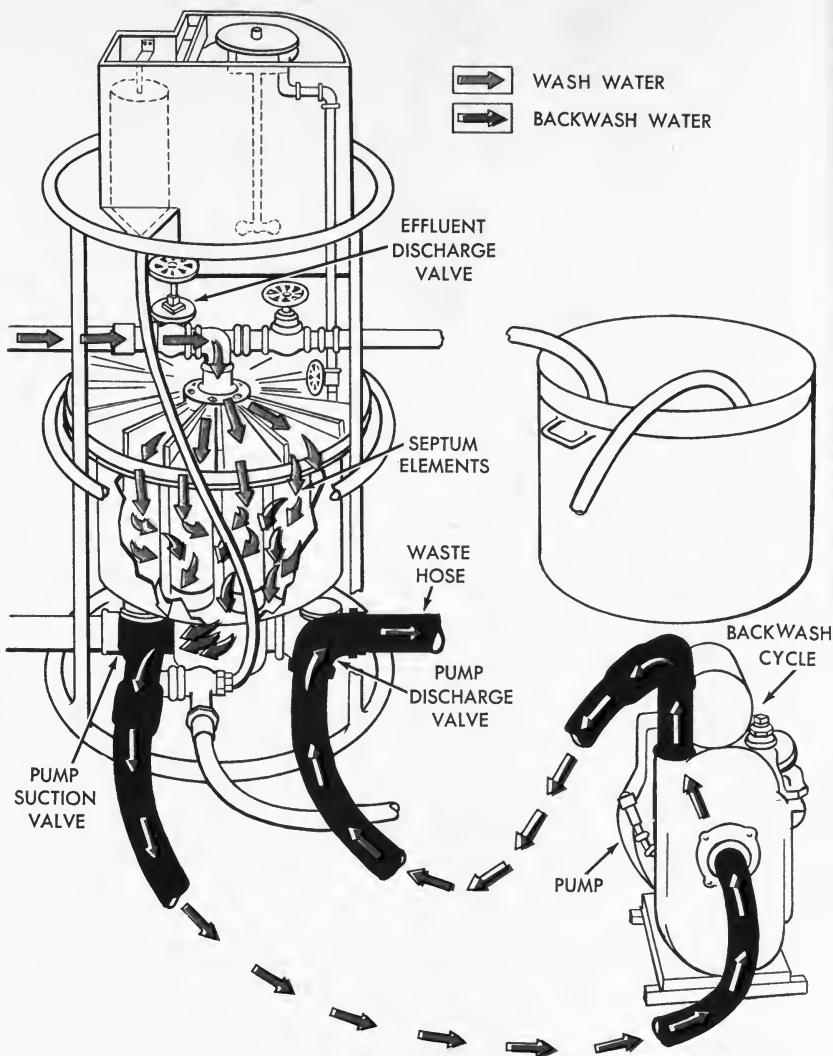


Figure 69. Flow diagram, backwash cycle, during operation of diatomite portable 50 gpm unit.

## Section VI. DISTILLATION

### 99. Uses

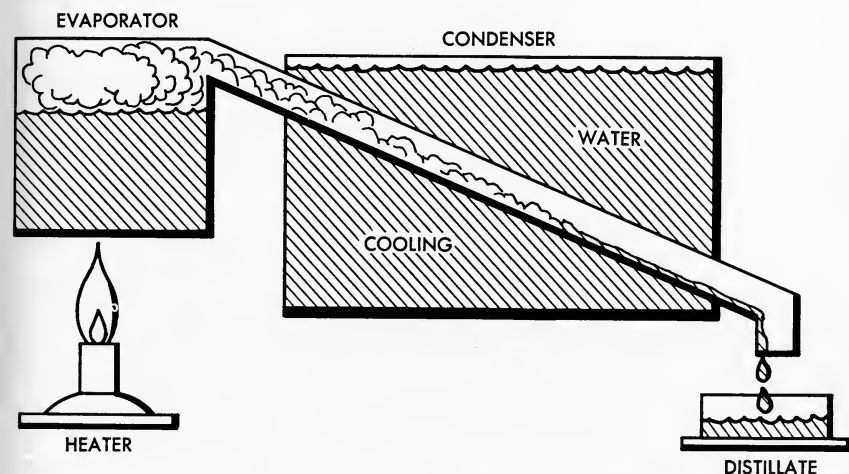
a. In areas where a satisfactory fresh water source cannot be located, and existing water treatment facilities are not usable, the distillation process can be used to obtain fresh drinking water from brackish water, sea water, or water containing excessive amounts of dissolved solids. Distillation is effective for removing radioactive contaminants from water.

b. Since the output of distillation equipment is limited and the process is expensive, its use is restricted to situations in which no



other process is adequate. Continuous flow or batch type water purification equipment is used whenever possible.

c. Distillation consists of heating water to form steam, separating the steam from the remaining water, and then cooling the steam so that it becomes water again (fig. 70). All dissolved solids remain in the equipment and noncondensable gases are vented to the air so that the resulting distillate is almost pure. Thus the distillation process is useful in producing water of an extremely high level of purity, and low in total solids. Despite this high degree of purity, all distilled water must be disinfected before being consumed by troops because of the possibility of recontamination during handling.



*Figure 70. Distillation in its simplest form.*

## 100. Principles of Distillation

As the water is heated to form steam or water vapor, and the vapor is separated and then cooled, solids dissolved in the water do not vaporize, but remain behind in the raw water. A large amount of heat which is not evidenced as a rise in temperature is required to change (vaporize) boiling water into steam. This is called the latent heat of vaporization. To change 1 pound of water to 1 pound of steam at 212° F., the latent heat of vaporization required is 970 British thermal units (Btu). A Btu is the quantity of heat required to raise the temperature of 1 pound of water 1° F. The latent heat remains in the steam, which will not condense until the latent heat is removed. The process whereby the latent heat is removed and the steam becomes water is called "condensation." A simple distillation unit is illustrated in fig-

ure 70. Heat flows through the bottom of the evaporator, enters the water, and changes the water to steam. The steam is condensed in the condenser, its latent heat of vaporization being transferred to the water surrounding the tubes. A portion of the cooling water which has picked up heat in passing through the condenser is generally used as feed water for the evaporator.

### 101. Multiple-Effect Distillation

*a.* The latent heat of vaporization produced in one evaporator may be used to generate steam in another evaporator. When the latent heat of vaporization of the steam produced in the first evaporator is used to produce steam in a second evaporator, the process is called double-effect distillation. In the triple-effect process, the latent heat of the steam generated in a second-effect evaporator is used to form steam in the third-effect evaporator.

*b.* Multiple-effect distillation is based on the fact that the temperature of compressed steam increases proportionately with the increase in pressure. Heat flows into the first-effect evaporator and changes some of the water to steam by furnishing the necessary latent heat of vaporization. The steam is confined, raising its pressure enough to increase the temperature to  $236^{\circ}\text{F}$ .

*c.* The steam from the first-effect flows through a coil immersed in the water of the second-effect. There its latent heat is transferred to the water, causing it to condense as distillate and changing an equal amount of second-effect water into steam. The steam is not confined as much as that from the first-effect, therefore, its pressure and temperature are less. The difference in temperature is essential for the transfer of the latent heat. Steam from the second-effect at  $224^{\circ}\text{F}$ . flows through a coil immersed in the water of the third-effect evaporator. Its latent heat is again transferred, causing all of the steam to condense as distillate and changing an equal amount of the third-effect water into steam.

*d.* The steam from the third-effect is not confined; therefore, its temperature is  $212^{\circ}\text{F}$ . It flows through a coil immersed in cool water where it transfers its latent heat to the water and condenses into distillate. The cooling water from the condenser can be used as feed water in the first-effect.

### 102. Thermocompression Distillation

*a.* In thermocompression distillation, the latent heat of vaporization of steam is again used to produce additional steam. The pressure and temperature of the steam generated in the evaporator are raised by compressing the steam. The compressed steam passes to the condenser section where it condenses, giving up its latent heat and causing more steam to form in the evaporator.

This steam is then compressed and the cycle repeated. The use of a combination evaporator-condenser with a steam compressor creates a closed heat cycle permitting the continued reuse of the latent heat of vaporization. The compressor is driven by a gasoline or diesel water-cooled engine.

b. Figure 71 illustrates the operation of a simple thermocompression distillation unit. Cold raw water flows through heat exchangers where it is heated almost to boiling by the outgoing streams of distillate and brine and by water from the engine that drives the compressor. The hot raw water flows into the evaporator-condenser, and is changed to steam by the steam condensing in the tubes. This involves the transfer of latent heat. The steam in the evaporator is drawn into the compressor where it is compressed and its temperature raised (from 212° F. to 222° F. in the diagram). The compressed steam flows back through the coils in the evaporator-condenser where it transfers its latent heat through the walls of the coil into the water in the evaporator section. This transfer of latent heat causes the steam to condense in the coils and changes the water in the evaporator into steam. This cycle will continue as long as the compressor runs.

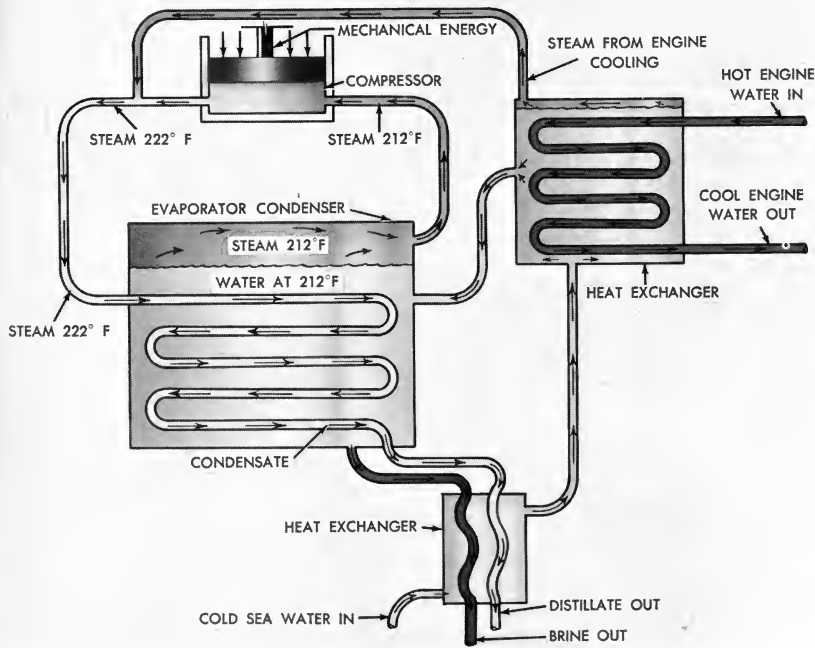


Figure 71. Flow diagram—thermocompression distillation.

**Figure 72.** Flow diagram, 1,200-gpd thermocompression distillation unit.

### 103. Distillation Equipment

a. *Thermocompression Type Equipment.* Standard Army distillation equipment is of the thermocompression type. Each unit is skid- or trailer-mounted to facilitate handling, and is assembled as a complete unit with power unit, pumping equipment, piping, and controls. Distillation units are depot items, issued on a need basis. Layouts will vary considerably, depending on the kind and amount of auxiliary equipment, such as water storage tanks, pumps, pipes, and fittings available in the depots or incident to the using unit. The Army thermocompression unit produces from 100 to 200 pounds of distillate per pound of fuel used. Standard thermocompression equipment is made in 1,200 gallon-per-day (gpd), 3,000 gpd, and 6,000 gpd capacity. The 1,200 gpd unit is shown in figure 72. These capacities are computed on the basis of a 20-hour-per-day production schedule. Detailed information on the units is available in TM 5-2053, TM 5-2065, and TM 5-2068.

b. *Auxiliary Equipment.* In areas without fresh water sources, distillation equipment must be used. Layouts will vary considerably, depending on the kind and amount of auxiliary equipment,

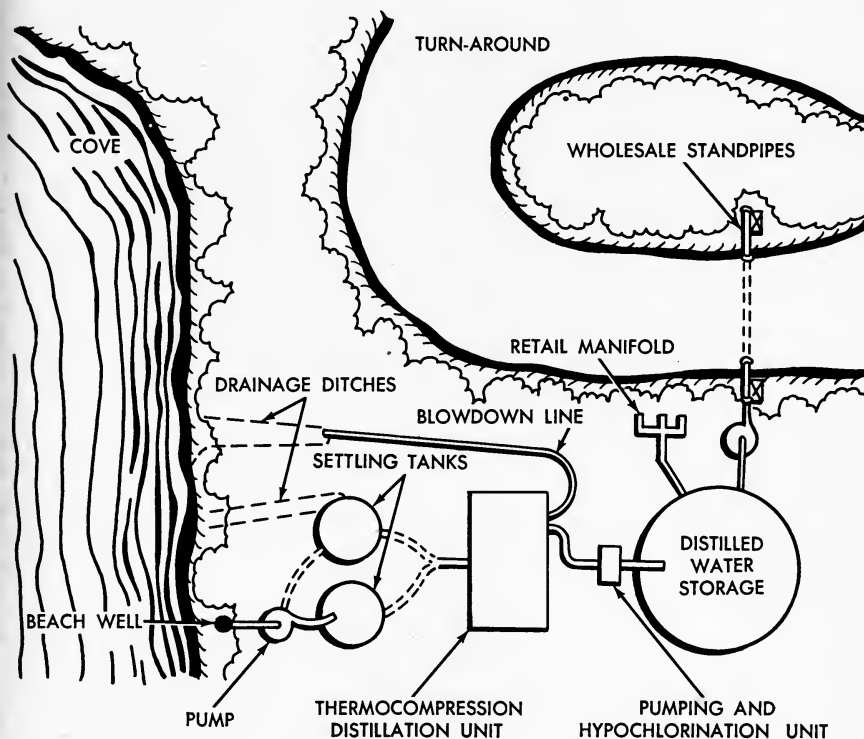


Figure 73. Layout for thermocompression distillation unit.

such as water storage tanks, pumps, pipes, and fittings available in the depots. The layout shown in figure 73 for a thermocompression distillation unit located in a sheltered cove includes the sea water intake, settling tanks for the salt water, storage tank for distilled water, and distribution facilities. Disinfection is accomplished by a pumping and hypochlorination assembly in the layout shown but may also be accomplished by adding hypochlorite to the water in the storage tank. The hypochlorite is mixed by circulating water through the pumps. The latter batch method is less desirable, especially on large tanks, and should be avoided when continuous operating equipment is available.

c. *Expedient Distillation.* When necessary, expedient stills can be improvised to produce potable water. All that is needed is a source of heat, a method of forming and collecting steam, and some kind of condenser. The efficiency of such expedients will be determined by the ingenuity of the design and the availability of materials. In expedient distillation of brackish or sea water, sufficient vapor-separating space or an ample baffle system must be provided to prevent carryover of salt with the steam. Care must also be taken to avoid getting salt in the distillate through the expedient condensing apparatus. To avoid building up steam pressure and endangering personnel, valves should never be used in the distillate line. Figures 74, 75, and 76 illustrate three variations of expedient distillation; they are described briefly below:

- (1) To operate the unit shown in figure 74, fill the drum with water to the level of the overflow pipe and start a fire under the drum. When the water boils, the steam passes through the condenser. When first putting the unit into operation, keep the feed valve closed until steam appears at the distillate outlet. Then pump water into the cooling-water inlet, adjusting the feed valve so the water level remains constant when the water level control valve is barely open. Discharge the remaining cooling water to waste.
- (2) Figure 75 shows a method of improving the distillation equipment shown in figure 74. The added water cooler is constructed exactly like the condenser and serves both to cool the distillate and to heat the feed water. To keep the feed water as hot as possible use only enough water to cause complete condensation.
- (3) The expedient equipment shown in figure 76 utilizes a long stretch of pipe as a condenser. More complete condensation will result if the pipe is bent into curves and immersed in a pit filled with water.

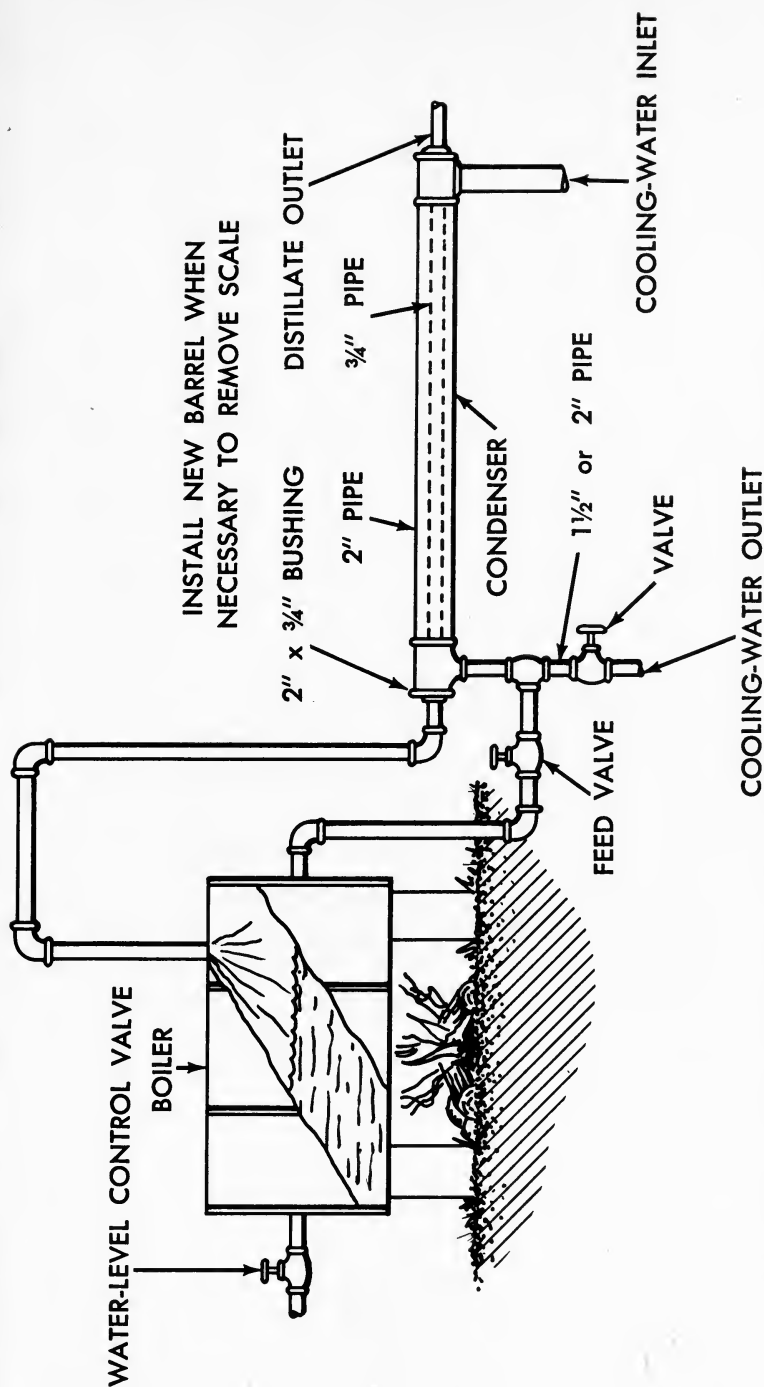


Figure 74. Expedient distillation apparatus (empty fuel drum,  $\frac{3}{4}$ -in. and 2-in. pipes and valves).

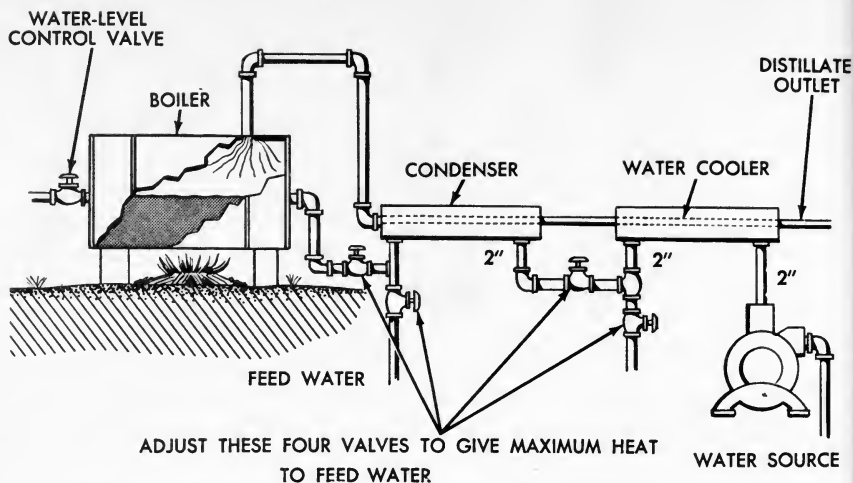


Figure 75. Expedient distillation apparatus (distillate cooler added).

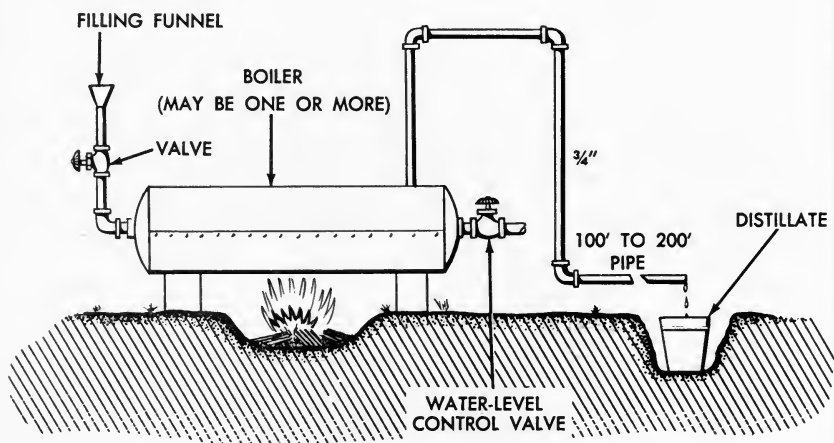


Figure 76. Expedient distillation apparatus (boiler,  $\frac{3}{4}$ -in. pipe and valves).

## 104. Production Efficiency

a. In order that distillation equipment may be operated continuously and efficiently at its rated capacity (20 hours a day), a proper maintenance schedule must be followed. The raw water should be as free as possible of silt, sand, and other foreign material. The appropriate technical manual should be consulted for guidance if any part of the unit fails to operate properly. Minor repairs should be made promptly, expedient repairs should be made as needed in emergencies, and the equipment should be re-conditioned as often as necessary to keep it in first-class shape.



b. The distillation equipment should be protected by side panels and other protective shields during high winds or cold weather. Since antifreeze solutions cannot be used, all cold weather shutdowns are considered permanent, and a distillation unit must be *completely* drained to prevent equipment from icing up. The appropriate technical manual should be consulted for information on temporary shutdowns under normal conditions.

## 105. Scale Control

a. Although large portions of the dissolved impurities remain in solution and are carried to waste in the distillation process, other impurities (magnesium hydroxide, calcium carbonate, calcium sulfate, and silica) remain within the equipment and form scale on the tubes and coils of the unit. This scale retards heat transfer, and thus increases pressures and temperatures and reduces output and economy. Therefore, scale must be removed periodically. Indications that descaling is needed include: a drop in output of 10 percent or more, an overloaded engine, or an increase in a pressure differential of over 3 pounds between compressor suction and discharge.

b. Detailed instructions for both manual and chemical cleaning of scale may be found in the appropriate technical manual for each unit. Frequent descaling with citric acid controls scale formation and reduces the length of time the distillation unit is withdrawn from service. Where feed water conditions do not change, a periodic descaling program can be set up. The acid dosage may be increased or decreased as required to obtain an efficient degree of descaling.

c. This cleaning takes about 2 hours and can be done without the disassembling and reassembling necessary for manual cleaning. The need for descaling will vary in relation to the various factors below:

- (1) The degree of alkalinity of feed water will affect both the frequency of cleaning and the concentration of chemical necessary in the acid cleaning method.
- (2) The higher the quantity of scale-forming *dissolved* solids the more often cleaning will be needed.
- (3) Maintenance of the proper quantity of water in the evaporator is important to prevent unnecessary scaling of the evaporator tubes.

## Section VII. TREATMENT OF CONTAMINATED WATER

### 106. Basic Considerations

a. If chemical, biological, or radiological warfare, or any combination of these, is used, the field water supply will inevitably

be involved. It is impossible to foresee what type of agent will be used, but effective security measures can decrease and counteract the hazards of all three types of agents.

b. Effective security involves prompt and accurate detection. Contamination by chemical agents usually, although not always, leaves significant signs which should arouse immediate suspicion. These are: drastic lowering of the pH value of the water; characteristic odors and tastes; and dead fish. If chemical contamination is suspected, tests with the AN-M2, Chemical Agents Water Testing Kit, should be performed immediately (ch. 6).

c. Advice and guidance from the Army Medical Service must be sought and followed carefully when water contaminated by CBR agents must be treated and used. The specialized training of Army medical personnel in the latest means of detection and treatment will aid water supply technicians in safeguarding the lives and health of the troops.

d. If contamination of any type, by CBR warfare agents or poisonous industrial wastes, is detected, every effort must be made to find an uncontaminated water source before considering treating and using water known to be contaminated.

e. If an uncontaminated source of supply is not available for use, permission must be secured from proper medical authority to proceed with treatment of the contaminated water.

## 107. Decontamination With Continuous Flow Type Equipment

a. *Removal of Chemical Agents.* When contamination by toxic chemical agents has been determined to be present in concentration beyond the tolerance shown in table XI (app. II), and the water must be treated and used, one of the four types of decontamination methods set forth in the table is used:

- (1) *Activated carbon.* This treatment is used when nitrogen mustard gases, sulfur mustard, or lewisite are present. Activated carbon is a relatively pure, finely powdered form of carbon which *adsorbs* many substances readily. It is an excellent adsorbing agent because of fineness and porosity of the carbon particles give it an enormous surface area. One cubic inch of activated carbon particles has an internal and external exposure area of about 20,000 square yards. The activated carbon is added to a pretreatment tank set up separately from the coagulator assembly. Raw water is pumped into this pretreatment tank from the source, and the activated carbon added: 600 ppm is generally sufficient. The water is allowed to remain in contact with the carbon for 30 minutes or longer, and is then pumped to the purification unit for the usual treatment.

- (2) *Aeration.* When hydrogen cyanide is the contaminant and the water is warm (70° F. or above), the aeration treatment is used. Water may be aerated by spraying it into the air, allowing it to flow over cascades, passing it through beds of coke, or passing air under pressure into the water. The spray method can be effectively used with Army purification equipment. Water can be recirculated through storage tanks or reservoirs by pumping the water out of the tank and spraying it back through an elevated strainer or nozzle attached to the discharge end of the hose (fig. 77).



*Figure 77. Aeration of water.*

- (3) *Superchlorination and dechlorination.* (See **Caution** below.) When hydrogen cyanide is the contaminant and the water is cold, or when one of the nerve gases is the contaminant, two pretreatment tanks should be used. Raw water is pumped into both tanks and superchlorinated by the addition of 100 ppm available chlorine from high strength calcium hypochlorite. (The calcium hypochlorite is added to the tanks prior to starting to fill them with raw water.) The water is then dechlorinated by the activated carbon treatment outlined in (1) above. By the use of two tanks, a continuous quantity of pretreated water can be made available to the coagulator in much

the same manner as two or more flocc tanks are used in the batch process of normal water treatment. It is important that the residue of activated carbon in the pretreatment tanks be kept in suspension. Pumps should be used for this purpose if necessary. The carbon is removed by the diatomite filters. After the water has been filtered the chlorine residual should be checked. If the residual is inadequate, postchlorination is necessary.

**Caution:** Calcium hypochlorite, a powerful oxidizer, and activated carbon, a reducing agent, will react violently, possibly resulting in fire or explosion, if mixed with one another in slurry form. The following safety precautions should be observed:

1. Do not store activated carbon and calcium hypochlorite near one another.
2. Do not use the same pail to prepare slurries of these two substances.
3. Keep both chemicals dry until actually ready for use.

*b. Removal of Biological Agents.* When the presence of chlorine resistant biological agents is reported by authorized detection agencies, the prescribed treatment in connection with continuous flow equipment is the superchlorination and dechlorination procedure outlined in *a*(3) above. A low pH, by acidification if necessary, is desirable.

*c. Removal of Radiological Agents.*

- (1) Radiological contamination may result from fallout of either fission products (radioactive isotopes) or unfissioned products (uranium or plutonium), as well as from blow-in or wash-in of radioactive dust, and from induced activity in dissolved materials in water and surrounding soil. Continuous flow equipment, when operated according to standard procedure, is capable of removing a large amount of such contamination. However, sources containing radiological contamination should be avoided if at all possible.
- (2) The efficiency of a given process for removal of radioactive materials from water is dependent upon the quantity of the contaminant which is in suspension in the water, and the quantity which is dissolved in true solution. Removal of material in suspension is relatively easy, since the purification procedure is designed to remove suspended matter and to clarify the water. Available information indicates that most of the radioactivity occurring in fallout and debris from the detonation of a

nuclear weapon is insoluble in water. This fact tends to simplify the decontamination problem.

- (3) Continuous flow type equipment, with auxiliary processing equipment when necessary, removes radioactive material from water by one or a combination of methods: pretreatment and coagulation and filtration. Coagulation and filtration are normal treatment given to all raw surface waters in operation of field purification units. Removal of suspended radioactive materials by this method is very high. Removal of *dissolved* radioactivity depends primarily upon the nature of the radioisotopes in question. The removal is negligible for strontium 90, iodine 131, and cesium 137, the three most hazardous materials. For certain other radioisotopes, such as yttrium, ionic removals well over 90 percent may be realized.
- (4) Pretreatment is suggested when the degree of radiological contamination indicates a combination of treatment methods, or when the more effective ion exchange equipment is not available. Pretreatment consists of batch slurring the contaminated raw water with a selected material having adsorptive and ion exchange capacity. The material of choice is clay, preferably of the montmorillonite type, high in hydrous aluminum silicate content. Raw water is slurred with 1,000 ppm for 30 minutes, and is then coagulated and filtered. This series of steps will remove most of the suspended radioactivity, and an appreciable percentage of the dissolved radioactivity. The advice of the Army Medical Service should be sought as to the most effective method of pretreatment.

*d. Removal of Industrial Wastes and Other Contaminants.* Occasionally there is no alternative to using a water source containing certain harmful industrial wastes. If it is necessary to use such a source, advice as to treatment should be sought from the Army Medical Service. Probably the most common industrial waste products are inorganic acids. These acids will be neutralized by the calcium carbonate (limestone) in the normal continuous flow purification procedure. Certain materials, as, for instance, arsenic, can be entrapped in a freshly prepared ferric hydroxide precipitate (iron floc), and thus will be eliminated in normal continuous flow treatment. Water found to contain petroleum products is generally allowed to settle in a pretreatment tank so that the oil will rise to the surface. The water is then drawn off from the bottom of the tank, treated with activated carbon if

necessary, and then subjected to the normal continuous flow treatment.

## 108. Decontamination Coordinated With Batch Method Equipment

*a. Removal of Chemical Agents.* When it has been determined that a water source has been contaminated with chemical warfare agents in quantities beyond the tolerances established in table XI (app. II), and there is no acceptable alternate source, treatment will be accomplished in accordance with the table. Generally, treatment with batch type equipment (fig. 78) will be similar to treatment with continuous flow equipment, previously described.

- (1) *Activated carbon.* This treatment is used for the same contaminants and proceeds in the same way as described in paragraph 107a(1). After the given contact time has elapsed, the water is pumped to the coagulation tank for the usual batch method type of purification treatment.
- (2) *Aeration.* The aeration treatment takes place in the pretreatment tank, and is used for the same purpose and performed in the same way as described in paragraph 107a(2). The water is then pumped to the coagulation tank for the usual batch purification treatment.
- (3) *Superchlorination and dechlorination.* In treating cold water contaminated by hydrogen cyanide or when one of the nerve gases is the contaminant, superchlorination and dechlorination are accomplished as described in paragraph 107a(3).

*b. Removal of Biological Agents.* Chlorine resistant biological agents are removed by superchlorination and dechlorination, as described in paragraph 107b. The water is tested for chlorine residual as it is pumped into the coagulation tank, to determine whether further chlorination is necessary, along with normal coagulation procedure.

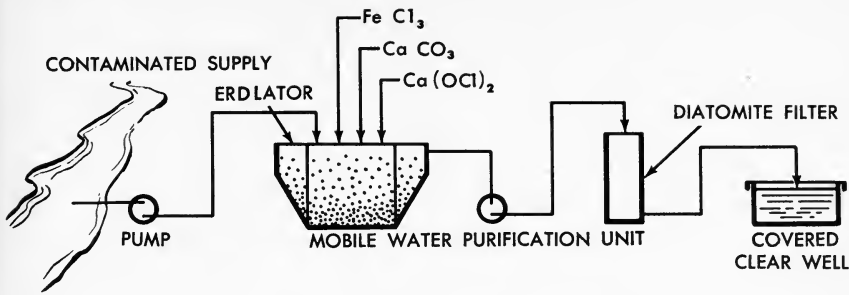
*c. Removal of Radiological Agents.* When radiological contamination cannot be avoided, 1,000 ppm of clay are added to the water in the pretreatment tank, and the water is agitated for thorough mixing. A contact period of 30 to 60 minutes is allowed. The radioactive particles in the water attach to the clay particles and settle out. The water is then subjected to the usual batch method treatment.

*Note.* The Army Medical Service must be consulted prior to processing water by this method.

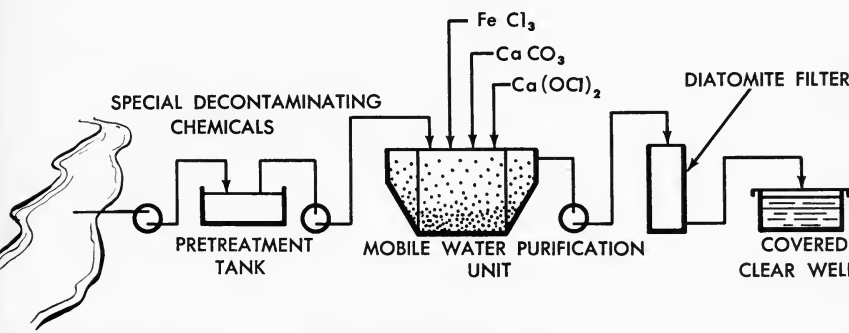
*d. Removal of Industrial Wastes and Other Contaminants.* If it is necessary to use a source thus contaminated, advice as to treatment should be sought from the Army Medical Service.

- (1) Usually, treatment with lime,  $\text{Ca}(\text{OH})_2$ ; powdered lime-

NORMAL TREATMENT



PRETREATMENT FOR BW AND CW AGENTS PLUS NORMAL TREATMENT



NORMAL TREATMENT PLUS POST TREATMENT FOR RADIOLOGICAL CONTAMINATION

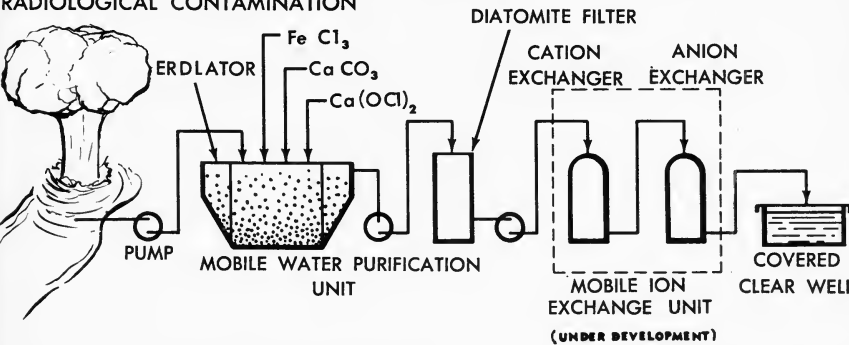


Figure 78. Comparison of standard treatment with processes for treating water contaminated by CBR agents—continuous flow method.

stone,  $\text{CaCO}_3$ ; or soda ash,  $\text{Na}_2\text{CO}_3$ , will neutralize any inorganic acids. In some cases, the entire contaminant (for example, sulfuric acid) may be precipitated by this neutralization. Soluble heavy metal salts may be precipitated, as are the insoluble carbonates, by hydrolysis with soda ash.

- (2) Arsenic presents a special problem, since the action of soda ash, alum, calcium hypochlorite, or activated carbon has no effect upon it. Ferric chloride, used in a treatment similar to the coagulation procedure followed with continuous flow equipment (par. 107d) will precipitate inorganic arsenic with the ferric hydroxide thus formed.
- (3) Petroleum and other non-water-soluble organic wastes may be removed from the water simply by retaining the water in a pretreatment tank and allowing the petroleum products to rise to the surface. The water is then drawn from the bottom of the tank and delivered to the coagulation tank. The final several inches of water, containing the "settled" oily contaminant, are run off to waste. Activated carbon is added to the floc tank, if necessary, to eliminate unpleasant tastes and odors resulting from the organic contaminant.
- (4) Phenolic resins and chemicals, when dissolved in water, are extremely poisonous. The Army Medical Service is final authority on any treatment and usage of water thus contaminated.

## Section VIII. SPECIAL WATER PURIFICATION PROBLEMS AND PROCEDURES

### 109. Taste and Odor Control

*a. Need for Control.* Tastes and odors in water are most commonly caused decay of organic matter and, when the raw water source is in or near populated areas, by industrial wastes. Tastes and odors which make water unpalatable must be removed. Use of free available chlorine (par. 78e(1)) and activated carbon will do much to prevent odorous combinations of chlorine with organic impurities in water.

*b. Break-Point Chlorination.*

- (1) With many waters, the relationship between the chlorine dose and the residual chlorine does not result in a straight line (denoting increase) but follows a curve. The chlorine residual increases with the chlorine dose up to a certain point, and thereafter remains fairly constant or falls off with increased application until finally, it starts up again. The point at which it starts up again is known as the "*break-point.*" It should be noted that the curve for water free of ammonia follows a straight line after the immediate chlorine demand has been satisfied.



- (2) This reaction is due to the presence in the water of ammonia and other forms of nitrogen. Oxidation of ammonia and reduction of chlorine are noted when the molar ratio of chlorine to ammonia is greater than one. A substantially complete oxidation-reduction process occurs in the neighborhood of a ratio of 2 to 1 and leads, in the course of time, to the disappearance of all the oxidizing chlorine from the solution.
- (3) Advantages of chlorinating to and beyond the break-point to obtain free available chlorine residuals are that most odors and taste normal to water are destroyed and rigorous disinfection is insured.
- (4) Break-point chlorination is essentially the provision of at least 90 percent free available chlorine and this essentially eliminates the formation of combinations of chlorine and organic impurities. Theoretically, Army procedures aim at the provision of break-point chlorination in obtaining the minimum residual requirement of free available chlorine.

*c. Methods of Removal.* Activated carbon is the most widely used single process for taste and odor removal. Aeration and copper sulfate treatment are also used. All three methods are described below. The method used will depend upon the substance or substances to be removed, and available equipment.

- (1) *Activated carbon.* Activated carbon is an excellent adsorbing agent to use in ridding water of unpleasant tastes and odors. It is also an effective agent for removal of organic color. It is insoluble and tends to float unless all particles are thoroughly wetted by being made into a slurry before being added to the water. When continuous flow equipment is being used, the activated carbon is added to the limestone feeder and added to the water with the limestone slurry. When batch type equipment is being used, the activated carbon may be added with the other chemicals in the coagulation tank. Being insoluble, it will not affect the pH value or chemical characteristics of water. One ounce of activated carbon per 1,000 gallons of water is usually adequate; however, dosages up to 1 pound per 1,000 gallons can be used, depending upon the kind and degree of impurities present. Use of activated carbon in much higher dosages for removal of chemical warfare agents is discussed in paragraphs 106 through 108.

*Note.* Treatment with activated carbon should always be made ahead of, or part of, the coagulation process, in order that the acti-

vated carbon and the various impurities which have been absorbed by it will be removed.

- (2) *Aeration*. This treatment, which consists of adding oxygen by exposing the water to air, was described in paragraph 107a(2). The process has a twofold action. Volatile taste- and odor-producing materials are released to the atmosphere and the action of the air upon readily oxidizable materials causes a precipitation of insoluble oxides and hydroxides. Removal of hydrogen sulfide is an example of the former action, while removal of iron is an example of the latter action. The aeration of water to rid it of the taste and odor of decomposing vegetable matter generally involves both actions.
- (3) *Copper sulfate*. If tastes and odors are caused by small living organisms in the water source, they may be controlled or prevented with use of copper sulfate. This treatment is most frequently used in lakes and reservoirs. The copper sulfate is applied either by towing a porous sack containing copper sulfate crystals behind a boat, or by spraying a solution over the surface of the water. The amount of copper sulfate used depends on the type and concentration of organisms present. Dosages should be controlled, due to the fact that amounts greater than 2.0 ppm will generally kill all fish in the water. The amount necessary to remove microorganisms has no detrimental effect, however, on human beings. Copper sulfate treatment is rarely used in field water supply for several reasons:
  - (a) The advantage to be derived from treating an entire lake or reservoir frequently does not warrant the expense of the treatment, when the length of time the water source is to be used is taken into consideration.
  - (b) The amount of copper sulfate used entails considerations of wild life, medical effects, and total water chemistry which are beyond the water supply technicians' area of operation.
  - (c) Superchlorination and dechlorination with activated carbon are effective for short periods although they are expensive for extended operations.

## 110. Water Softening

Water softening is most likely to be necessary when water is being supplied to laundries, heating-type units, and other such facilities involving boilers and steam equipment. The two most commonly used processes for softening water are the lime-soda treatment and the zeolite process.

a. *Lime-Soda Process.* Lime Soda Ash Softening consists of the application of these materials to the raw water. Lime,  $\text{Ca}(\text{OH})_2$ , reacts with the *soluble* calcium and magnesium bicarbonates and forms *insoluble* calcium carbonate and magnesium hydroxide. Soda ash,  $\text{Na}_2\text{CO}_3$ , reacts with the soluble noncarbonate compounds of calcium and magnesium to precipitate insoluble calcium and magnesium compounds but leave sodium compounds in solution. The physical operation of adding lime-soda ash and removing the precipitates is similar to that in the conventional coagulation-filtration process for bacteria and turbidity removal.

b. *Zeolite Process.* Zeolites used in water softening are complex compounds of sodium, aluminum, and silica which have the faculty of exchanging bases. They are often called "green sand" because of the color of natural zeolite. Synthetic zeolites are also available. When water containing calcium and manganese compounds passes over the zeolite, the calcium and manganese are exchanged for the sodium in the zeolite. In this way the water is softened and its sodium content increased. When the sodium of the zeolite is exhausted, it is regenerated by applying a sodium chloride solution. Another exchange is made, and the resulting concentrated solution of calcium and magnesium chloride is discharged to waste. The operating rate varies directly with the thickness of the zeolite bed. The time between regenerations depends on the characteristics of the water and the total amount of water applied. The need for regeneration will be evident when hardness is no longer removed. The zeolite process can only be used on water which has been treated for the removal of turbidity.

### III. Iron and Manganese Removal

Oxidation by aeration, followed by sedimentation and filtration, is the most common method of removing iron and manganese. They are oxidized to insoluble ferric oxide and manganese oxide by this process. The same methods may generally be used to remove both iron and manganese, although when they are present together in water, removal is more difficult. Combinations of iron and manganese with organic matter may require aeration in trickling beds containing coke. This also is followed by sedimentation and filtration. In some cases superchlorination followed by sedimentation and filtration will in itself remove these two substances. The addition of lime,  $\text{Ca}(\text{OH})_2$ , followed by sedimentation and filtration, is another method which has been used successfully for removal of these substances. Iron and manganese removal is not normally required in the production of field drinking water.

### II2. Corrosion Control

Ordinarily, corrosion control is not an important problem in

field water supply. However, steel tanks and piping are subject to corrosion if in contact with water with a low pH value. Therefore, occasionally, when water is to be transported by pipeline, carried or stored in metal containers for considerable periods of time, or used for special purposes, it will be necessary to condition the water to prevent corrosion of the steel equipment. Lime,  $\text{Ca}(\text{OH})_2$ , or soda ash,  $\text{Na}_2\text{CO}_3$ , are added to the water to raise the pH value to approximately 8 and thus reduce its tendency to corrode.

### 113. Removal of Schistosomes and Protection of Personnel

In areas where schistosomiasis is known to be present, wells and springs not subject to contamination by drainage and surface runoff should be used as water sources in preference to ponds and sluggish streams. However, where schistosomes are found in water which must be used as a source, the safety measures described below must be observed by water supply personnel:

*a. Filtration and Disinfection.* All standard diatomite filters of Army issue are dependably capable of mechanically removing the cercariae of the schistosomes from water. A representative of the Army Medical Service will determine what change the presence of schistosomes causes in the local chlorination policy.

*b. Protection of Water Supply Personnel.* Personnel required to wade or place their hands in untreated water known to contain schistosomes should wear boots and rubber gloves because the schistosomes can enter the body through the skin. Similar precautions should be observed when handling waste from filters being operated on the backwash cycle.

### 114. Purifying Water for Small Units

*a. Water Sterilizing Bag.* As discussed in paragraph 78f, the water sterilizing bag (lyster bag) may be used to disinfect small quantities of water when no other purification equipment is available. Detailed procedure for disinfection of water in the lyster bag is given in FM 21-10.

*b. Lyster Bag—Special Conditions.* Certain conditions require more than normal chlorination. These include the presence in the water of especially resistant disease organisms, waters with a pH of 8 or above, cold water, and water containing large amounts of organic or contamination materials. When any of these conditions is present, sufficiently higher chlorine residuals to safeguard the health of the troops will be used upon recommendation of the Army Medical Service representative.

*c. Canteen, With Iodine Tablets.* A canteen of water may be purified by placing one individual water purification iodine tablet in the canteen. The water is allowed to stand for 5 minutes, shaken, and allowed to stand another 10 minutes before being

consumed. A 20-minute period is allowed for cold water. Two tablets per canteen are used when the water is dirty or discolored.

*d. Canteen, With Calcium Hypochlorite.* If individual purification tablets are not available, water may be purified in canteens using calcium hypochlorite ampules. One ampule is dissolved in a full canteen of water and the resulting strong solution is used to purify water in other canteens. One canteen capful of the solution is added to each full canteen of water to be treated. The canteens so treated must be well shaken and allowed to stand for 30 minutes before the water is consumed. Two capfuls of the concentrated solution must be used to disinfect clear water suspected of containing schistosomes or amebic cysts. Three capfuls must be used to disinfect turbid or colored water.

## **115. Removal of Radioactive Sludge From Tanks**

The use of batch type equipment to remove radioactive materials from water results in a highly radioactive sludge in the pretreatment tanks. This sludge should be discarded as follows:

*a.* A pit should be dug sufficiently deep to contain the sludge, in a location that will prevent drainage back into the stream. The area should be marked off with tape for protection of personnel.

*b.* Backwash and sludge in tanks is flushed through a discharge hose connected at the base of the tank and drained into the pit.

*c.* The insides of the tanks are next scrubbed thoroughly with GI soap and trisodium phosphate, flushing all residue through the discharge hose and into the pit.

*d.* After scrubbing, the tanks are checked for radiation with a radiation detection meter. If radiation is detected the tanks are scrubbed again until no further readings are obtained on the meter.

*e.* When all of the sludge has been flushed from the tanks and there is no more need for the pit, it is covered with dirt from the excavation, and marked to show that radioactive waste has been buried.

## CHAPTER 6

### DETECTION OF CBR AGENTS IN WATER

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#### Section I. DETECTION

##### 116. Responsibilities

a. The Corps of Engineers and the Army Medical Service have responsibilities for detection of CBR agents in water as explained in paragraph 5. However, it must be emphasized that a representative of the Army Medical Service *should be consulted immediately* upon suspicion of contamination of a water source by CBR agents so that a laboratory type test can be made by trained personnel.

b. In addition to normal water treatment processes, water supply personnel must be constantly on the alert to detect indications of actual use of CBR agents. The unusual taste of water, or the presence of dead fish or animals in unusual numbers or situations should be significant. See FM 21-40 for a detailed discussion of indications and symptoms.

##### 117. Test for Toxic Chemical Agent Contaminants

a. *Precautions.* The Chemical Agent Water Testing Kit (AN-M2), for detection of toxic chemical agents (fig. 79), which is a part of the water quality control set, is used to detect water sources so contaminated that ordinary field treatment methods cannot make the water potable. In using the kit, the following precautions should be carefully observed:

- (1) Samples of water for these tests must be taken directly from the source in question, and as nearly as possible at the point and depth from which the water would be drawn.
- (2) Tests should not be made on treated water because chemical reactions brought about during treatment may cause misleading results. (The main purpose of the kit is to detect contamination by toxic chemical agents in raw water. *It is not designed for use in the control of treated water.*)
- (3) When a source is found to be contaminated, every effort should be made to find a source that tests negative.

Permission must be obtained from a medical officer to treat a contaminated source.

- (4) Nitrazine paper (provided by the kit) should not be used to determine pH and chlorine if the color comparator is available.
- (5) A pH less than 6.0 is cause for suspicion, because nearly all natural waters have a pH well above 6.0. However, highly colored swamp waters may have a pH below 6.0. A considerable drop from the normal for these waters should be considered suspicious.
- (6) A chlorine demand greater than 5 ppm is cause for suspicion. However, dissolved vegetable matter may cause a higher chlorine demand.

*b. Directions for Performing Tests.*

- (1) **Read directions thoroughly.** All steps must be performed in the exact order given.
- (2) Obtain a water sample in a canteen cup without excessive disturbance of the water source. This water will be used for all tests except the chlorine demand test.
- (3) After using any of the tablets or reagents, be sure to close the vial with the matching colored cap immediately.
- (4) Start the arsenic test. While the arsenic test is developing, perform the other tests.

## 118. Arsenic Test

*a.* Pour the suspected water into the bottle P to the mark nearer the bottom of the bottle.

*b.* Place two tablets from vial A into the bottle. Swirl to dissolve.

*c.* Take one test strip from vial B and carefully insert it into the tube L, bending the strip near the top so it will remain upright in the tube. Touch only the top end of the strip. Keep test strip dry.

*d.* When the tablets from vial A have dissolved, add five pellets from vial C to the contents of bottle P, and promptly fit the tube L assembly into the bottle.

*e.* Let react for 20 minutes. If the solution is cold, warm the bottle between the hands.

*f.* Remove the test strip from the tube L and note the length of the yellow to brown stain. A stain  $\frac{1}{4}$  inch or more indicates a positive test; a stain less than  $\frac{1}{4}$  inch indicates a negative test.

## 119. Mustard Test (Including Nitrogen Mustards and Cyanogen Chloride).

*a.* Rinse a test tube with suspected water, and carefully fill the tube to about  $\frac{1}{2}$  inch depth with the suspected water.

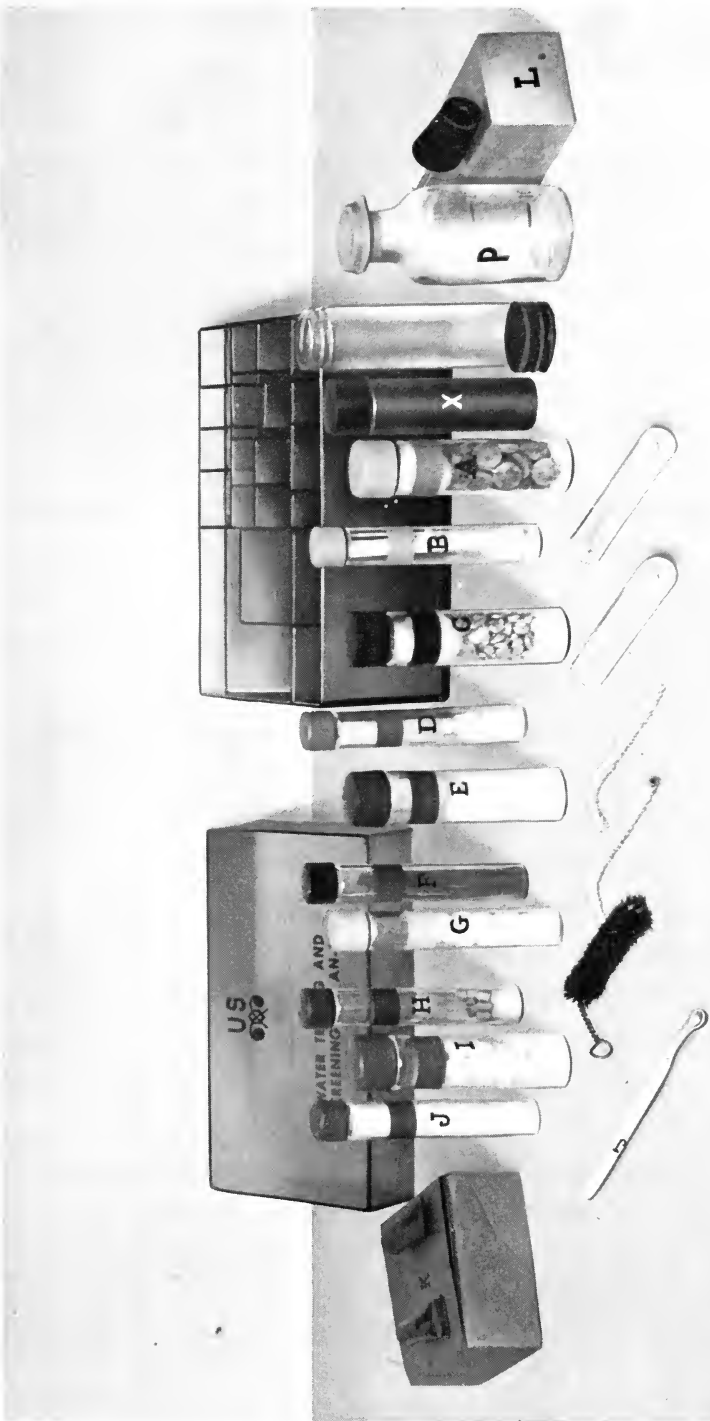


Figure 79. Chemical Agent Water Testing Kit (AN-M2).



b. Add one tablet from vial D and agitate for 3 minutes. Bring the solution to a boil with a match, lighter, or other source of heat. (The test carried out without the flame is less sensitive but will detect amounts of nitrogen mustards likely to cause serious casualties.) Allow the solution to stand for 5 minutes. During cold weather keep the tube warm in hand or inside pocket for an additional 5 minutes. A yellow color in the solution is positive for cyanogen chloride.

c. Break one tablet from vial E in half and add both halves to the test tube. Agitate the test tube gently, observing against a white background for any change of color in the liquid (or in the curd) from white to red or blue. Any visible color change, even if it fades rapidly, indicates a positive test for mustard or nitrogen mustards. A yellow color indicates cyanogen chloride. A white color indicates a negative test.

## 120. pH Test

Dip one strip of test paper from vial F into the suspected water. Remove and compare the resulting color of the test paper with the color chart. pH of less than 6 indicates possible contamination.

## 121. Chlorine Demand Test

a. Fill a canteen with the suspected water to within 1 inch of the top, add three tablets from vial G, screw on the cap, and shake vigorously for 5 minutes. Allow the solution to stand for 5 minutes.

b. Fill the plastic tube X to the bottom of the yellow band with water from the canteen. Add one tablet from vial X, swirl until it is completely dissolved, and compare the color of the solution with that of the yellow band on the tube.

c. A positive test is indicated by no color or color lighter than the yellow band. A negative test is indicated by an orange color or a color darker than the yellow band.

## 122. Nerve Agents

*Note.* Do not perform this test in direct sunlight.

a. Rinse bottle P three times with the suspected water, fill the bottle to the second mark with the water, and add one pellet from vial H. Swirl the solution to dissolve the pellet. If a yellow or green color appears, discard the solution and test as described in *g* below. If no yellow or green color is formed, continue as follows:

b. Rinse one test tube three times with suspected water from the canteen cup, and fill the test tube one-half full with the suspected water. Break one pellet from vial I in half, add both halves to the test tube, and shake to dissolve.

c. With scoop J add one level measure of powder from vial J to the test tube and shake for 2 minutes.

d. Pour the contents of the test tube into the bottle P, place the plastic cap on the bottle, and shake well for 2 minutes.

e. Break the tip of one of the tubes in carton K and add the contents to the bottle. Replace the plastic cap and shake for an additional 2 minutes. Add enough water from the canteen cup to bring the top level of the solution into the neck of the bottle just below the yellow band and let stand for 5 minutes.

f. A yellow color in the upper layer equal to or darker than the yellow band on the bottle is a positive test for nerve-agents and for certain toxic insecticides. A yellow color in the lower water layer indicates very dangerous concentrations of nerve-agents. With time, the yellow band on the bottle may fade. In this case, a comparison may be made with the yellow band on the plastic tube used for the chlorine demand test.

g. Rinse the bottle P and fill to the second mark on the bottle. Add one pellet from vial I and shake to dissolve. Add one level scoop of powder from vial J followed immediately by one pellet from vial H. Place the plastic cap on the bottle and shake well for 2 minutes. Continue as specified in *e* and *f* above.

h. In the absence of a highly positive chlorine demand test, no color or a color lighter than the yellow band indicates a negative test for nerve-agents.

## 123. Taste and Odor

a. If the arsenic test, mustard test, chlorine demand test, and nerve-agents test are negative and if the pH is 6 or above, carefully smell and taste a sample of the suspected water.

b. A positive test is indicated by:

(1) A lacrimating or chlorinous odor.

(2) A biting and/or peppery chlorinous taste.

(3) Any taste or odor of a known toxic chemical agent.

c. Absence of all tastes and odors will indicate a negative result, but not necessarily a safe water. A negative test is also indicated by the presence of only those odors and/or tastes normally characteristic of natural waters.

## 124. Interpretation of Tests

Water is considered CONTAMINATED AND UNSAFE for treating if one or more of the following results are obtained:

Arsenic test .....positive

Mustard test .....positive

pH test .....pH below 6

Chlorine demand test .....positive

Nerve-agent test .....positive

Taste and odor test .....positive

Water is considered safe for treatment by the usual methods if the pH is above 6.0 and all other contamination tests are negative.

## 125. Detection of Biological Agents

a. The bacteriological examination of water is performed by the Army Medical Service as part of its role in military water supply. The Medical Service inspects water points and sources, and advises the proper authorities as to methods of purification which may be used to produce a safe drinking water.

b. The Corps of Engineers presently has no test for detection of biological agents. The Chemical Agent Water Testing Kit (AN-M2) is currently being revised to include tests for all chemical agents in water. The kit will provide containers for sampling and shipping water samples to appropriate laboratories for analysis for biological and radiological contaminants.

## 126. Radiological Detection

a. *Army Medical Service.* The Army Medical Service is responsible for the quantitative analysis of radioactivity in water. In addition it will—

- (1) Provide continuous information on the quality of raw and treated drinking water as pertains to its radioactivity.
- (2) Conduct detailed radiological surveillance of streams, lakes, and underground waters throughout the field army area to determine their general acceptability for use as water supply sources. Guidance to engineer water supply units, based on this surveillance, should be continuously available.
- (3) Perform periodic test and analysis for radioactivity of the water furnished by engineer water points. Trained personnel will make these tests in a field laboratory using scaler-type equipment. Analytical results should be available to operating personnel within a few hours from the time the samples are collected.
- (4) Make frequent, but not continuous, evaluations of engineer water purification equipment in the field army area to assure that the performance of the equipment in removing radioactivity is satisfactory.

b. *Corps of Engineers.*

- (1) The Corps of Engineers has a need and the responsibility to make initial qualitative tests for radioactivity at proposed water point sites. These tests can be performed in the field by use of the Radiac Set, AN/PDR-27J.

These instruments are currently available to units for use by survey teams. One is also issued per water purification set.

- (2) Every effort should be made to avoid the use of a water source containing radiological contamination. If such a source must be used, on-site radiation monitoring procedures must not be relied on as a basis for determining the acceptability of water for its radioactive content. Readings obtained by use of the radiac meter are in milliroentgens per hour (mr/hr) and give an *indication that the water contains radioactivity, only*. Quantitative test and the final determination as to whether or not the water can be used is an Army Medical Service responsibility.

## Section II. PROTECTION OF PERSONNEL

### 127. Protective Clothing and Accessories

In the event of widespread use of CBR agents, water supply personnel must be provided some degree of protection if they are expected to continue their mission. In addition to the normal hazards caused by these agents, the removal of radioactive materials from water by batch type equipment creates a highly radioactive sludge in the tanks which, eventually, must be discarded by the operators. Details on protective clothing and accessories can be found in TM 3-303, TM 3-304, and TM 3-4240-202-15.

### 128. Additional Protection Techniques

Additional protection techniques which will aid in protection of personnel are—

- a. Common sense should be used by all operators to avoid injury by sources known to be contaminated.
- b. Immunization records should be kept current to provide protection against biological agents.
- c. Personnel should learn to “mask” quickly and not eat, drink, or breathe in any of the CBR agents.
- d. CW symptoms and protective measures should be known by all personnel.
- e. Personnel should be trained in the application of first aid and self aid.
- f. Personnel should be familiar with the unit CBR SOP.
- g. Communication channels should be kept open to the water supply personnel in order to keep them informed of the enemy and friendly situations.

## CHAPTER 7

### USE OF EXISTING FACILITIES

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#### Section I. INTRODUCTION

##### 129. Basic Procedures

a. Although it is a basic rule of field water supply that, wherever possible, existing facilities should be utilized, this manual has dealt mainly with the development of an original water supply in the field, because units seldom come across ready-developed water installations they can use. Occasionally, however, when moving into or near a captured or occupied city or area, Army Forces find an existing facility at hand.

b. In such cases, the system should be examined to see if it can provide a water supply for immediate military use. If existing water facilities can be put to use with less expenditure of time, effort, and equipment than it would take to develop a new military source, a decision should be made to use the already-established works. The same holds true of certain *parts* of the existing works: source, pumps, treatment plant, distribution system, storage facilities—whatever can be used more economically than can be established new.

c. Several key points should be kept carefully in mind, however, in making the final decision. One point is that all water, from whatever sources, must be considered unsafe for drinking until proved otherwise by competent Army Medical Service authorities. Consequently, provision will have to be made for disinfecting the water. In addition, existing facilities will have suffered some damage, in a great many cases. When this has happened, the commander responsible for selecting a water source and developing the supply must evaluate the extent of the damage, and arrive at an estimate of the time and materials needed to make necessary repairs. The team obtaining data for the commander's guidance must carry out its work accurately and quickly, since field sources must be capable of providing a prompt water supply. Waterworks plans, maps, and records should be obtained if possible and studied when making a reconnaissance. Informa-

tion from local inhabitants may also be utilized. These sources will reveal much information about the system that will help the commander arrive at a final decision.

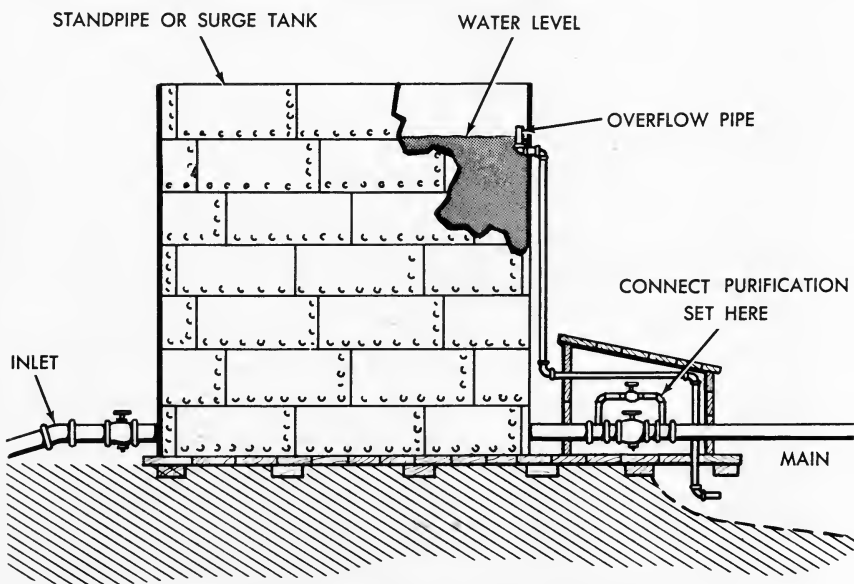
*d.* The quality of the water is another phase of the reconnaissance that needs careful attention. Water from the existing facility should be carefully tested. It may have been polluted or contaminated, or both, either accidentally or intentionally. Treating it and bringing it up to Army standards might place a greater load on the Army's own purification equipment than would the development of an original supply.

*e.* In examining the extent and seriousness of the damage to existing facilities, water supply personnel should take into consideration any military operations—underway or planned—which will necessitate additional water supply facilities to meet the demand. Hospitals or depots may be established and the health of the local population will have an effect on military operations. In such a case, the water supply must provide adequate quantity to meet these requirements, in addition to normal troop supply.

*f.* Information that may be helpful in taking over a fixed water supply facility will be found in TM 5-660, TM 5-661, TM 5-704, TM 5-297, and TB Med 229.

### 130. Temporary Connections

Once it has been determined to make use of existing facilities, attention should be given to whether emergency measures are needed to provide an immediate water supply.



*Figure 80. Surge tank with valve house.*

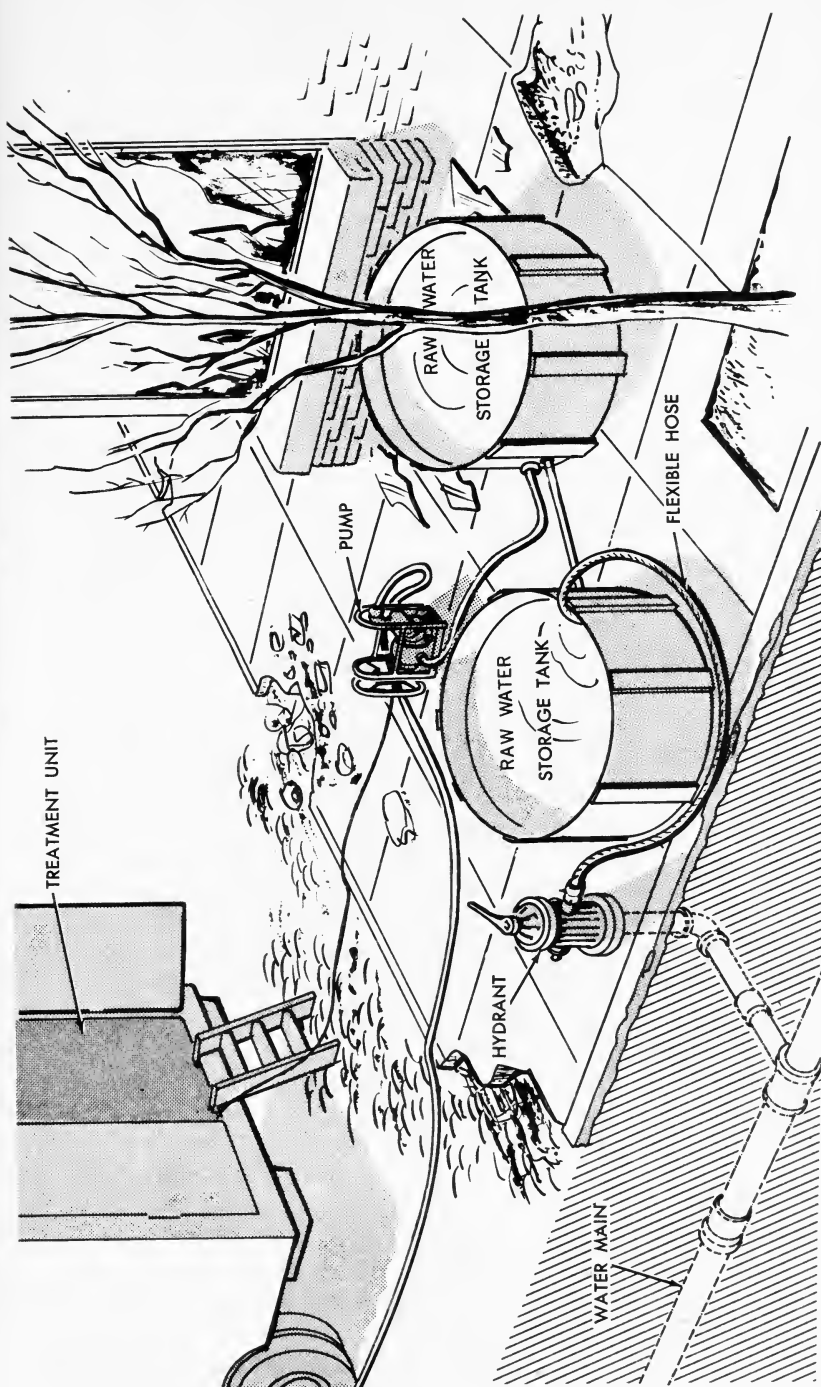


Figure 81. Hydrant used as water source.

a. Complete rehabilitation of existing water supply facilities, and the question of whether or not it is to be undertaken, are beyond the scope of this manual. However, repairs to a damaged system in order to fill immediate military needs will often take more than a few hours. Meanwhile, certain temporary connections can usually be set up to provide an emergency water supply.

b. Water contained in reservoirs and auxiliary tanks can usually be treated for immediate use. A connection generally can be made at the main-valve bypass (fig. 80). Water can be obtained from hydrants, as shown in figure 81. An adapter can be fabricated with pipefitting tools to allow direct connection of the water purification unit to the hydrant. Even fountains, troughs, and pools may yield emergency supplies of water in limited quantity, although here the Army Medical Service will maintain surveillance as to quality.

c. Existing pipelines must be thoroughly inspected before being used. Several pipes of similar type may have been laid in the same trench, and severed by enemy action. If pipes that have been severed in this way are to be reconnected, it is imperative that both sections of pipe be thoroughly inspected and explored. Failure to do so may result in a cross-connection which would allow passage of a contaminating substance such as sewage or waste water to enter the potable water main.

## Section II. REPAIRING EXISTING FACILITIES

### 131. Planning

When temporary connections have been set up, the next step is to organize the planning of such repairs as are needed to fill immediate military needs. A thorough reconnaissance will reveal the extent of damage to the source, pumps, treatment plant, distribution system, and storage facilities. In the following discussion it is assumed that none of these portions of the system has been damaged to the extent that lengthy, expensive repairs are needed—or else that any portion of the works so damaged can be bypassed completely and the system still be made operational with the use of other expedients.

### 132. Sources

a. The water supply source of an existing facility is the part most likely to be used even if the entire facility is not utilized. Another part likely to be put to use is the storage system (par. 136). Damage to springs and infiltration galleries can often be quickly repaired. Damage to large reservoirs is usually confined to the walls or levees, dam control works, and intake structures.



When the storage capacity of a reservoir has been seriously impaired, the reservoir can sometimes be put back into use at a reduced capacity, and additional emergency settling tanks can be set up to compensate. When a well casing has been damaged, a new inner lining can sometimes be installed and the well quickly put back into operation.

b. Breaks in pipelines or aqueducts, and damage to open channels which carry the water to the treatment plant, are usually localized. Ordinary construction methods and materials can be used when it is necessary to repair these, and the same applies to damaged sections of the walls, levees, or dams which impound the water for a reservoir.

### 133. Pumps

Damage to low-lift pumps at or near the water source and to high-lift pumps which serve the distribution system may result from bombs, artillery fire, or the deliberate action of a retreating enemy. When two similar pumps are damaged, the parts from one may be used to repair the other. This "cannibalism" in pumps, and elsewhere throughout the mechanized equipment as well, often makes it possible to restore the system to service, even though at a reduced capacity. To operate the pumps, an adequate source of power is of course essential. Most plants have a standby as well as a primary power source.

### 134. Treatment Plants

a. *Use of Expedients.* A damaged treatment plant can often be operated by reducing the rate of treatment, or by omitting some part of the treatment process, with the exception of disinfection, until repairs are made. Sometimes, certain operations which previously had been done automatically will have to be performed manually, and other expedient measures will have to be devised. Substitutes should be brought into use whenever possible for damaged pieces of equipment that cannot be replaced, or for which replacements would be a long time in arriving.

b. *Buildings.*

- (1) Waterworks plant buildings may be damaged not only from fire, but from the effects of high explosive bomb fragments, blast, and shock. Since the function of plant buildings is to house and protect machinery and equipment, the damage to the buildings themselves should be regarded as of secondary importance. After the debris is cleared away, the first objective must be to place the plant back in operation. After that, temporary repairs to the buildings, necessary to protect the equipment, can be made. Plans for reconstruction of the damaged build-

ings will wait upon the overall decision as to repairs and rehabilitation.

- (2) Temporary shelters to protect the equipment from the weather can be of frame construction, although they have the disadvantage of being flammable. If somewhat more permanent repairs are undertaken, the construction material is likely to be concrete, brick, or masonry. Standard construction methods for these materials are used in making these repairs.

*c. Treatment Equipment.*

- (1) Many times damage to the basins, filters, controls, piping, feeders, and other equipment is slight enough so repairs can be made rather quickly, to allow at least partial treatment or operation at a reduced rate to fill immediate military needs.
- (2) If some filters are damaged, the filter rate on those remaining in operation can be increased by opening the rate controllers or raising the operating head on the filters. If sand-type filters have been used, sand which is clean, but which does not necessarily comply with the rigid specifications for filter sand, may have to be located and used as an expedient.
- (3) Undamaged coagulation and sedimentation basins may be operated at increased rates but will probably require increased dosage of coagulants because of the shorter retention periods. The increased operating rate of treatment facilities will usually result in some sacrifice in efficiency, but in emergencies is preferable to using untreated water.
- (4) In certain instances, treatment processes such as iron removal and softening can be omitted. Although they are desirable processes, they do not affect the sanitary quality of the water, and should not be included if they limit the plant capacity. Processes used for removal of taste, odor, and color can also be omitted in an emergency, but should be placed in operation as soon as possible if the water is noticeably unpleasant.
- (5) Chemical feeders usually can be repaired by replacing the damaged parts. Parts may be obtained from stockpiles, if such exist, or salvaged from other damaged feeders. Expedient repairs to damaged chemical feeders will be necessary when there are no parts; certain military equipment can often be adapted. When feeders are damaged beyond repair, chemicals can be added manually, until a more efficient expedient is improvised.
- (6) Modern treatment plants have numerous automatic con-

trols which, when damaged, require manual operation at greatly reduced operating rates. Damage to pump controls, for instance, will make manual starting and stopping of the pumps necessary. Feeders, as stated above, can be operated manually, and so can control devices and other automatic equipment. Improvised controls—floats, venturi tubes, other needed parts—can be fabricated to replace those damaged and to get the system into operation.

*d. Treatment Processes.* Primary emphasis should be placed on the quality of chlorination practices employed at damaged water plants. Even greater reliance must be placed on disinfection to insure the production of potable water when filters are operated at higher than design rates or substitute sand is used in sand filters.

### 135. Distribution System

*a.* The most vulnerable part of a waterworks facility is its distribution system, composed of water mains, valves, and hydrants. Mains, for example, are easily fractured by bomb burst. The resulting breaks not only introduce the danger of contamination, but also allow loss of large quantities of water. Fortunately the distribution system is also the part that can most easily be dispensed with, or substituted for, in taking over a municipal facility.

*b.* Early repair of fractured water mains is desirable and vital. It is a difficult and hazardous job, which will be performed by an engineer unit. Emergency action will consist of isolating the damaged section by closing a minimum number of valves. This action serves to conserve the supply, and to prevent loss of pressure, flooding, and contamination.

*c.* The required repair operations can be planned, scheduled, and undertaken at a later date. Meanwhile, temporary repairs are sometimes called for to control water wastage and maintain the necessary pressure for fire protection. This type of repair consists of such steps as capping or plugging fractured mains and bypassing main breaks with pipes or fire hose (figs. 82–84). Mechanical and slipover fittings can be used advantageously in making this type of water main repairs. The repair of a major break in a water main is sometimes complicated by the extensive excavation required, in which case other methods should be used if possible in order to establish a water supply for immediate military needs. Figure 83, for example, shows methods of bypassing bomb craters with a minimum of excavation.

*d.* When there has been bombing, there is an ever-present danger of contamination through undetected cracks, pulled-out serv-

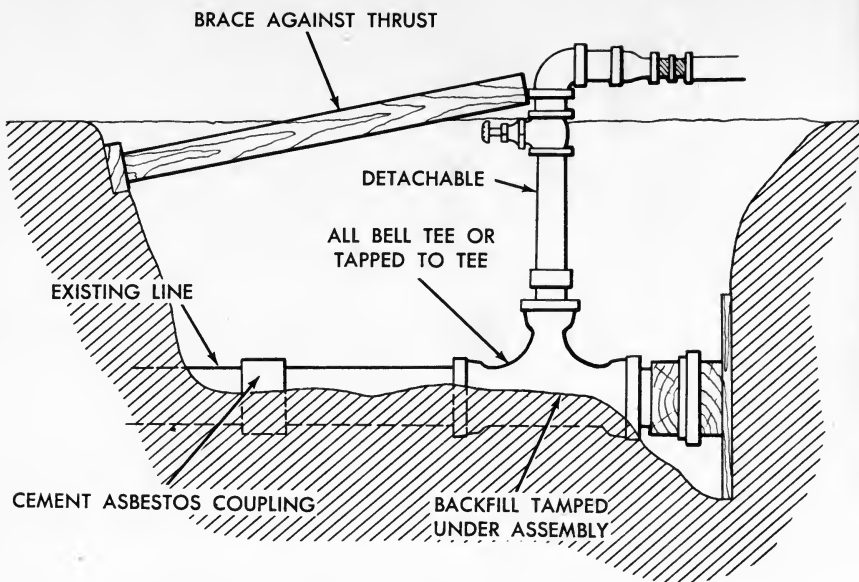


Figure 82. Vertical fire-hose bypass.

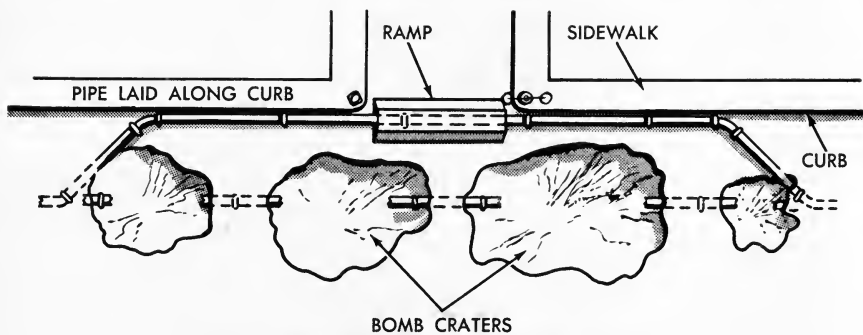
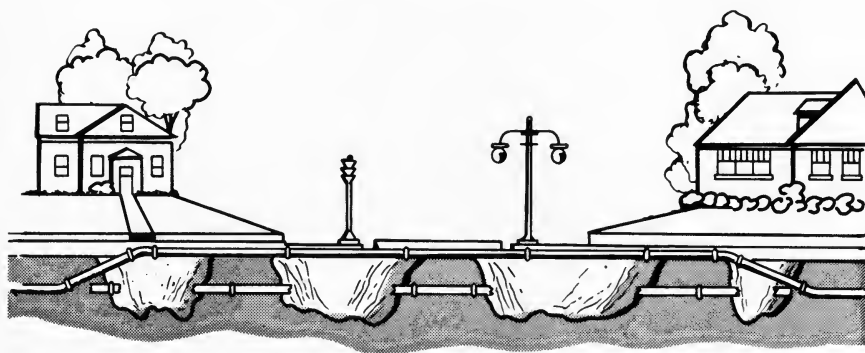


Figure 83. Pipe bypass of bomb craters.

CENTER MAY ALSO BE BY-PASSED WITH FIRE HOSE CONNECTED  
TO BROKEN PIPE OR WITH AID OF SPECIAL CAPS OR PLUGS

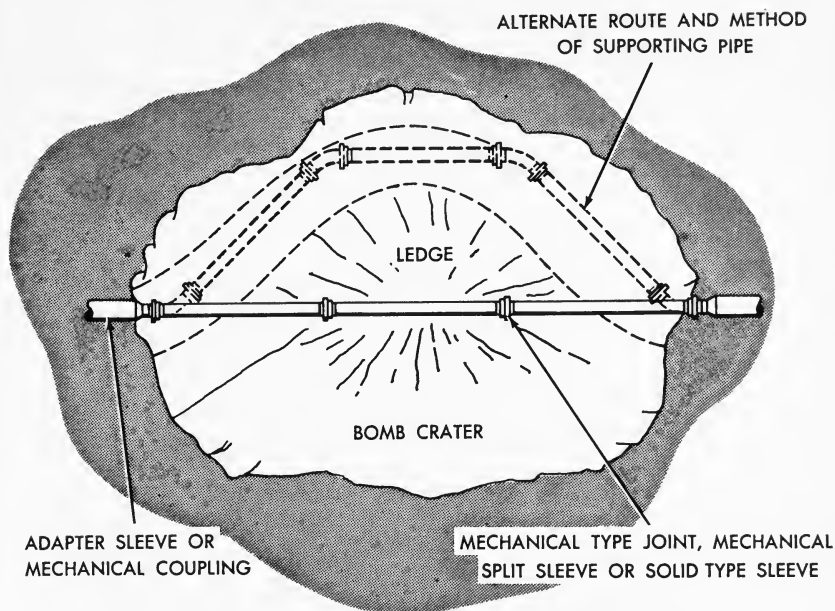


Figure 84. Pipe bypass of a single bomb crater.

ice taps, and leaking joints. After repairing mains, as after any repair operation to a water system, a thorough disinfection must be performed. Water with a high chlorine residual is the best safeguard in the meantime. Instructions on disinfection are given in paragraph 139.

### 136. Storage Facilities

a. Storage facilities are important to military operations because they may be brought into service as water points. Along with the sources, they represent the parts of existing water facilities which are most likely to be pressed into immediate military use, regardless of the decision as to whether the rest of the system will be utilized.

b. Storage facilities include open reservoirs, underground and surface storage tanks, standpipes, and elevated storage tanks. The character of the damage and the repair called for will depend not only upon the type of military action to which they have been subjected, but also upon their type of construction. Earth reservoirs, for example, must be observed closely for seepage and erosion. Damage to underground reservoirs or storage facilities is often light, due to the fact of their being underground and

covered. Surface reservoirs, and ruptured standpipes, can usually be repaired with common construction materials. For example, leakage through concrete or masonry structures can be stopped by plugging open cracks or joints. Steel tanks may require welding to make them watertight. If elevated tanks have been toppled from high supports, they are usually damaged beyond repair; if this is the case, material from them may be used for other repair elsewhere. Close examination must be made of storage facilities and their contents, to detect either accidental or deliberate pollution or contamination.

### Section III. OPERATION OF EXISTING FACILITIES

#### 137. Problems Involved

a. The operation of existing water supply facilities will bear at least some resemblance to that of fixed Army water supply in-

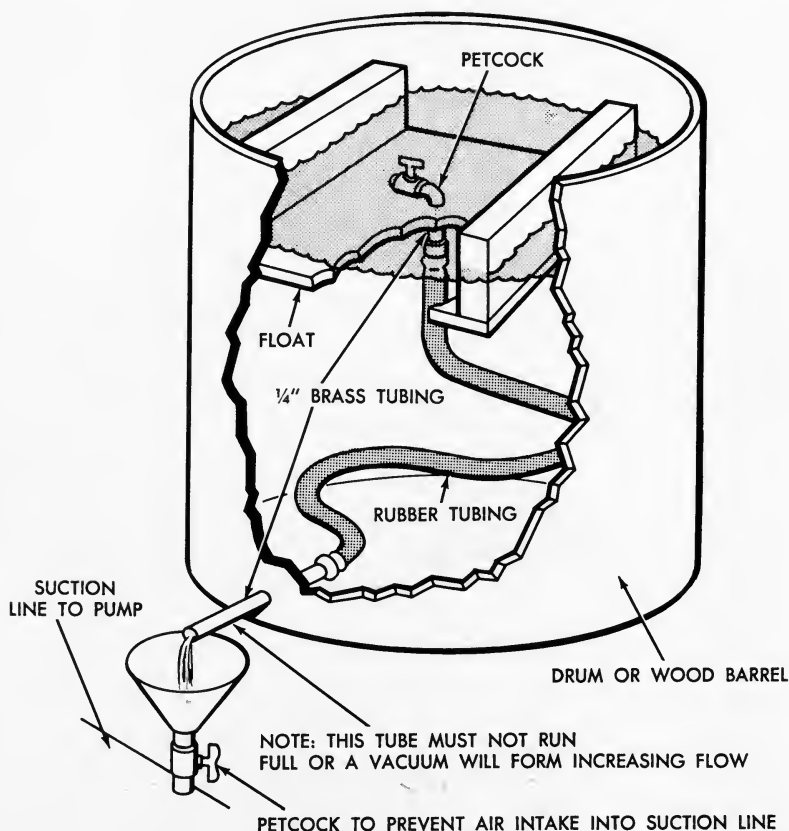
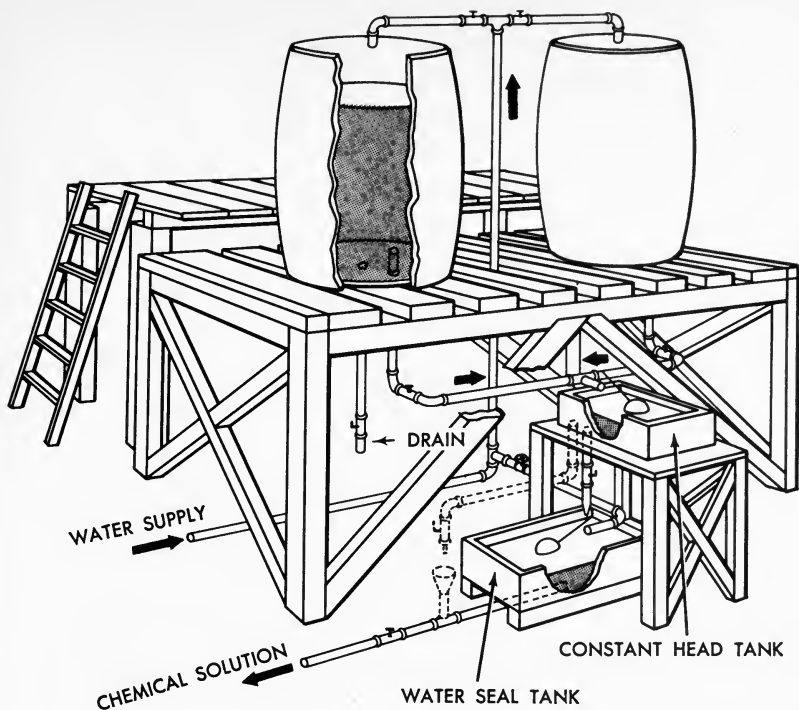


Figure 85. Improvised constant-flow chlorinator.



NOTE: WATER SEAL TANK IS NECESSARY WHEN CHEMICAL SOLUTION IS DISCHARGED INTO AN OPEN CONDUIT, BASIN OR PUMP WELL

*Figure 86. Emergency solution feeder.*

stallations. Even under ideal conditions, the maintenance and operation of these facilities will require a knowledge of plant layout, because of the many types and arrangements of treatment equipment. This is one reason for obtaining and studying as many of the plans, maps, and records of the facility as possible. They will give information on plant capacity, operating characteristics, location of control and bypass equipment, and other information that will be helpful in operation of the equipment.

b. The problems encountered in taking over and operating an existing municipal waterworks facility, or part of it, will vary greatly, depending upon such things as the type of installation, the extent and kind of damage, whether the cooperation of civilians familiar with the equipment is sought and received, and the availability of materials for immediate repairs.

### 138. Use of Local Civilian Personnel

Whenever possible, services of civilians familiar with local

installations should be used. Their value cannot be overemphasized. They can often supply important information concerning stockpiles, furnish necessary records, aid in making repairs, and operate the local facility. However, it must be borne in mind that, because of the danger of sabotage and intentional contamination of the water, such civilians must be carefully screened and selected. Also, they must be closely supervised to forestall repair and rehabilitation beyond immediate military necessity.

### 139. Disinfection

a. In emergencies such as may exist during the process of taking over and operating a municipal facility, disinfection is the most effective method of safeguarding the water supply against the danger of contamination. When the situation demands it, increased dosages of chlorine will be utilized to provide the higher chlorine residuals required to insure potable water.

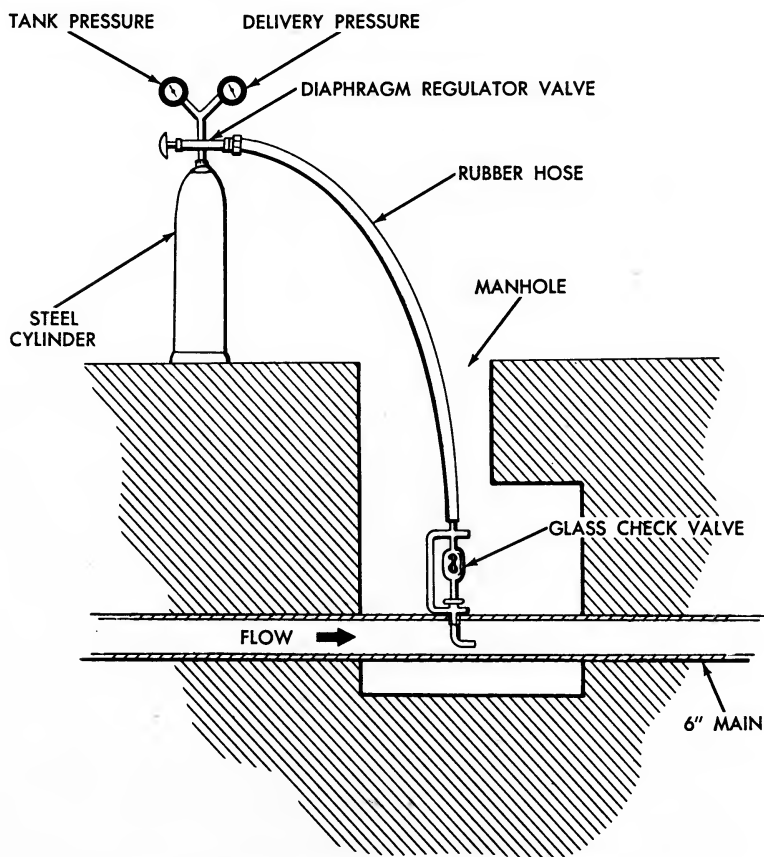


Figure 87. Emergency improvised chlorinator.



b. Since the chlorinating equipment of most plants is large enough to provide normal dosages only, improvised methods of application are often required. Figures 85 and 86 illustrate how constant rate hypochlorite feeders may be improvised for gravity application of chlorine solutions into open conduits, clear wells, or into the suction side of a pump. Figure 87 illustrates another improvisation. These expedients are most effective for small plants. For large plants, manual application of calcium hypochlorite may be necessary. Commercial chlorinators should be used where available. Whatever repairs are needed to reduce or eliminate the emergency should be performed as rapidly as possible.

c. Certain contaminants may appear in the water supply of fixed installations. For example, it has been found that some over-sea sources contain arsenic in natural compounds, not as a result of industrial wastes. Also, although the practice of handling water in lead pipes has greatly declined, lead poisoning can result from this and other sources, and should be guarded against (pars. 63-65).

d. Following repairs, disinfection is always a necessity. Water mains, water storage structures, and every other part of the system must first be cleaned and disinfected before being put

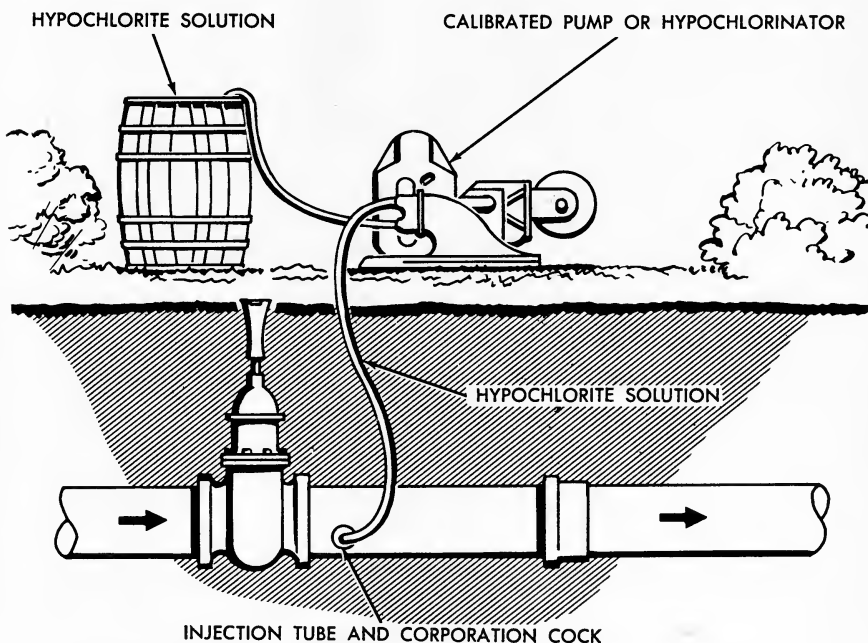
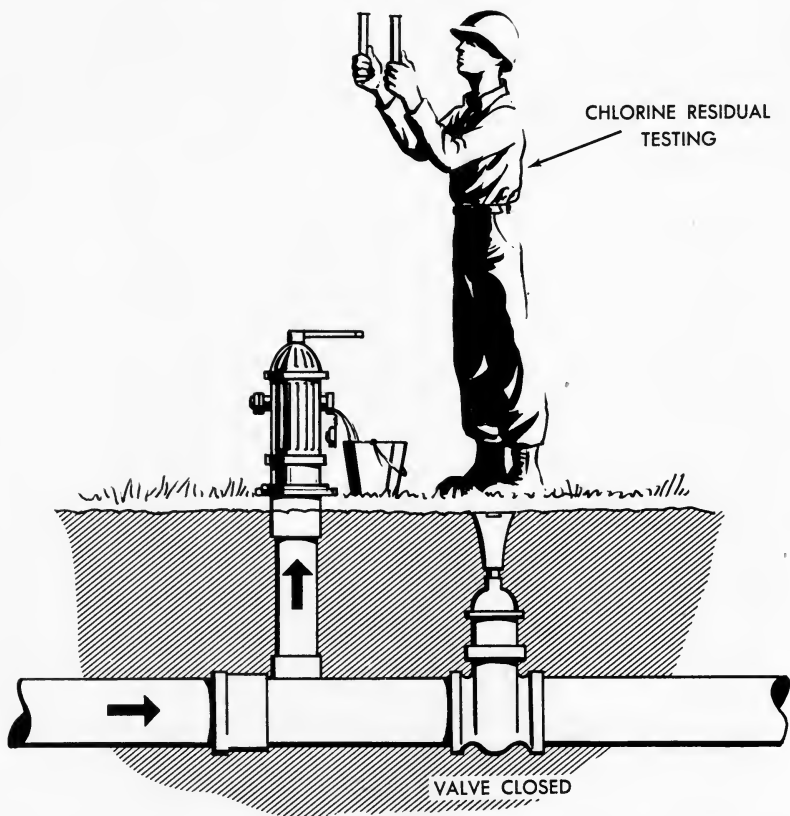


Figure 88. Typical arrangement for water main disinfection with hypochlorinator

back into operation. Figure 88 shows a typical arrangement for water main disinfection with a hypochlorinator. Residual chlorine is checked as shown in figure 89. Elevated tanks, standpipes, or reservoirs used for storage of treated water may be disinfected by spraying or washing the inner surface with a strong chlorine solution, or by filling the structure or structures with water having a high residual, usually 100 ppm, for a 24-hour period. Repaired water mains should always be filled with 100 ppm chlorine residual water for at least 24 hours before use. The water originally filling the mains, reservoir, tank, or standpipe must be wasted before placing the facility back in operation.



*Figure 89. Testing for residual chlorine during water main disinfection with hypochlorinator*

## APPENDIX I

### REFERENCES

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DA Pam 108-1	Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.
DA Pam 310-series	Military Publications.
AR 320-5	Dictionary of United States Army Terms.
AR 320-50	Authorized Abbreviations and Brevity Codes.
FM 5-1	Engineer Troop Organizations and Operations.
FM 5-15	Field Fortifications.
FM 5-20	Camouflage, Basic Principles and Field Camouflage.
FM 5-34	Engineer Field Data.
FM 5-35	Engineers' Reference and Logistical Data.
FM 21-5	Military Training.
FM 21-10	Military Sanitation.
FM 21-30	Military Symbols.
FM 21-40	Small Unit Procedures in Nuclear, Biological, and Chemical Warfare.
FM 21-41	Soldier's Handbook for Nuclear, Biological, and Chemical Warfare.
FM 101-5	Staff Officers Field Manual; Staff Organization and Procedures.
FM 101-10	Staff Officers' Field Manual; Organization, Technical and Logistical Data.
TM 3-216	Military Biology and Biological Warfare Agents.
TM 3-303	Impregnating Set, Clothing, Field, M3; Impregnating Outfit, Clothing, Field M1; Kit, Testing, Impregnate-In-Clothing, M1.
TM 3-304	Protective Clothing and Accessories.
TM 3-4240-202-15	Operation and Organizational, Field and Depot Maintenance: Mask, Protective, Field, M17.

TM 5-297	Wells.
TM 5-301	Staff Tables of Engineer Functional Components System.
TM 5-302	Construction in the Theater of Operations.
TM 5-303	Bill of Materials and Equipment of the Engineer Functional Components System.
TM 5-350	Military Pipeline Systems.
TM 5-545	Geology and its Military Applications.
TM 5-660	Operation of Water Supply and Treatment Facilities at Fixed Installations.
TM 5-661	Inspection and Preventive Maintenance Services for Water Supply Systems at Fixed Installations.
TM 5-704	Construction Print Reading in the Field.
TM 5-2035	Water Purification Unit; Hand Operated, Knapsack Pack, Filter Pad Type, 1/4 GPM.
TM 5-2053	Distillation Unit; Diesel-Engine-Driven, Skid-Mounted, Thermocompression Type, 6,000-Gallons Per Day, Mechanical Equipment, Model S7D.
TM 5-2065	Distillation Unit, Gasoline-Engine Driven, Skid Mounted Thermocompression Type, 3,000 gpd, Badger Model.
TM 5-2068	Instructions for Operation and Maintenance of Distillation Unit; Thermocompression Type, Gasoline, Trailer-Mounted, 1,200 Gallons Per Day, Badger.
TM 5-2102	Water Purification Equipment; Diatomite Set No. 2 Pack, 15-GPM.
TM 5-2103	Water Purification Equipment; Diatomite Set No. 3 Portable, 35-GPM.
TM 5-2104	Water Purification Equipment; Diatomite Set No. 4, Portable, 50-GPM.
TM 5-4610-202-10	Operator's Manual: Water Purification Unit, Trailer Mounted, Electric Driven, AC-DC, 115 V, Single Phase, 60 Cycles, 1/20 to 3/4 HP, 600 GPH (Met-Pro Model 600-2500) (FSN 4610-649-8387).
TM 5-4610-203-10	Operator's Manual: Water Purification Unit; Van Type Body Mounted, Electric Driven, AC 115 and 208 Volt, Single

and 3 Phase, 60 Cycle 1/70 to 2 HP,  
3,000 GPH.

- TM 5-4610-204-10      Operator's Manual: Water Purification  
Unit; Van Type Body Mounted, Elec-  
tric Driven, AC 115 and 208 Volt, Single  
and 3-Phase, 60 Cycle, 1/70 to 2 HP,  
1,500 GPH.
- TM 8-285                Treatment of Chemical Warfare Casualties.
- TB CML 79             Water Testing Kit, Poisons, M4A1.
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## APPENDIX II

### TABLES

*Table I. Daily Water Requirements in Temperate Zone*

Unit consumer	Conditions of use	Gallons per unit consumer per day	Remarks
Man.....	In combat:		
	Minimum.....	1/2-1.....	For periods not exceeding 3 days, when operational rations are used.
		2.....	When field rations are used.
	Normal.....	3.....	Drinking plus small amount for cooking or personal hygiene.
	March or bivouac....	2.....	Minimum for all purposes.
	Temporary camp....	5.....	Desirable for all purposes (does not include bathing).
	Temporary camp with bathing facilities.	15.	
	Semipermanent camp.	30-60.....	Includes allowance for waterborne sewage system.
	Permanent camp....	60-100.	
Vehicle.....	Level and rolling country.	1/8 to 1/2.....	Depending on size of vehicle.
	Mountainous country	1/4 to 1.....	Depending on size of vehicle.
Hospital.....	Drinking and cooking.	10 per bed....	Minimum, does not include bathing or water for flushing.
	With waterborne sewage.	50 per bed....	

*Table II. Quantity and Quality of Water Needed by Construction Equipment*

Equipment	Size	Quantity	Purity of water
Rock crusher.....	225-T.....	60,000 gpd	No special purification. Sea water usable.
Concrete mixers.....	.....	18,000 gpd	Potable; minimum of organic matter. Acid alkali free.
Concrete paver.....	.....	60,000 gpd	Sea water may be used but decreases concrete strength by 20%. Extra cement may be used to offset this effect.
Asphalt plant.....	.....	1,000 gph	Alkali free. Low sulfates.
Steam jenny.....	.....	.....	Potable; low calcium and magnesium.
Steam boiler.....	200-hp.....	2,000 gpd	Do.
	w/receiver....	1,000 gpd	Do.
Three car heater (for asphalt plants).	.....	50 gph	Do.
Water distributor....	1,000 gal.....	1,000 gal per 100 yd of 8' road.	No special purification. Salt water acceptable.
Compaction.....	.....	Variable	Any available water accepted. Sea water actually preferable for certain jobs.
Vehicle radiators.....	.....	...do.....	Potable; calcium and magnesium lower than 400 ppm.
Asphalt rollers.....	.....	...do.....	Potable; free of organic matter.

*Table III. Common Impurities in Water*

Suspended impurities	Organisms.....		Some cause disease.	
	Algae.....		Cause taste, odor, color, turbidity.	
	Suspended solids.....		Cause murkiness or turbidity.	
Dissolved impurities	Salts	Calcium and magnesium.	Bicarbonate...	Causes alkalinity, hardness.
			Carbonate....	Causes alkalinity hardness.
			Sulfate.....	Causes hardness.
			Chloride.....	Causes hardness, corrosive to boilers.
		Sodium.....	Bicarbonate...	Causes alkalinity.
			Carbonate....	.....Do
			Sulfate.....	Causes foaming in steam boilers.
			Fluoride.....	Causes mottled enamel of teeth.
			Chloride.....	Causes salty taste.
	Iron	.....	Causes taste, red water, incrustations on metals.	
	Manganese	.....	Causes black or brown water.	
	Vegetable dye	.....	Causes color, acidity.	
	Gases	Oxygen.....	Causes corrosion of metals.	
		Carbon dioxide.....	Causes acidity, corrosion of metals.	
		Hydrogen sulfide.....	Causes odor, acidity, corrosion of metals.	
		Nitrogen.....	No effect.	



*Table IV. Contents of Supply Drawers*

Compartment number	Item	Quantity
	Left-hand supply drawer	
1	Funnels.....	2
	pH comparator tubes.....	2
2	pH color disks.....	2
3	Screw cap for 4-ounce solution bottle.....	4
	Screw cap for 4-ounce narrow-mouth bottle.....	2
	Screw cap for 8-ounce solution bottle.....	2
	Screw cap for 8-ounce wide-mouth bottle...	4
4	Boxes of filter paper.....	3
	Right-hand supply drawer	
5	Flashlight holder.....	1
6	8-ounce wide-mouth bottle.....	1
	Towel.....	1
7	Flashlight.....	1

*Table V. Contents of Pipette, Spare-Parts, and Instructions Drawers*

Compartment number	Item	Quantity
	Pipette and spare-parts drawer	
8a	Dropper pipettes tray w/six 1-ml pipettes..	1
8b	Screw-cap dropper pipette (2-oz bottle)....	2
	Screw-cap dropper pipette (4-oz bottle)....	4
	Dropper pipette, 1-ml.....	2
	Rubber bulbs (extra).....	6
9	Test-tube brushes.....	2
	Instructions drawer	
10	Loading plan (folded).....	1
	TM 5-700 (to be carried in drawer at all times).	1

Table VI. Contents of Reagent Drawers

Compartment number	Item	Quantity
	Left-hand reagent drawer	
11	4-ounce solution bottles (empty), titrating..	4
12	4-ounce solution bottles (empty), soap titrating.	2
13	4-ounce solution bottles, indicator:	
13a	Orthotolidine.....	1
13b	Bromthymol blue.....	1
13c	Bromcresol purple green.....	1
13d	Cresolred thymolblue.....	1
14	4-ounce narrow-mouth bottle:	
14a	Sulfuric acid.....	1
14b	Silver nitrate.....	1
14c	Soap.....	1
14d	Barium chloride.....	1
14e	Empty bottle.....	1
15	2-ounce bottle w/dropper:	
15a	Phenolphthalein.....	1
15b	Methyl orange.....	1
15c	Potassium chromate.....	1
15d	Empty bottle.....	1
16	½-ounce bottle w/dropper:	
16a	Cresolred-thymolblue.....	1
16b	Bromcresol purple green.....	1
	Right-hand reagent drawer	
17	8-ounce solution bottles:	
17a	Sulfuric acid.....	1
17b	Soap.....	1
17c	Silver nitrate.....	1
17d	Barium chloride.....	1
17e	Turbidity.....	1
17f	Zeo-karb-na.....	1
17g	Sample bottle.....	1
18	25-ml graduate and holder.....	1
19	8-ounce wide-mouth bottle:	
19a	Alum.....	1
19b	Soda ash..	1
20	4-ounce solution bottles w/graduated drop- per:	
20a	Alum solution.....	1
20b	Soda-ash solution.....	1

*Table VII. Contents of Bottom Shelves A and B*

Compartment number	Item	Quantity
	Left-hand bottom shelf A	
21	pH and chlorine comparator . . . . .	1
22	Water testing and screening kit (AN-M2) for detection of chemical warfare agents.	1
23	Coagulation test set w/four 8-ounce wide- mouth bottles.	1
	Right-hand bottom shelf B	
24	Turbidimeter w/four-ounce solution bottles.	1
25	Measuring cup, 1,000-ml . . . . .	1

Table VIII. Properties of Chemicals Used to Coagulate or Adjust Alkalinity of Water

Chemical	How used	How shipped	Weight (lb/cu ft)	Dose (grains/gal)	Effective pH range	Remarks
Ammonium alum. $\text{Al}_2(\text{SO}_4)_3$  ( $\text{NH}_4$ ) <sub>2</sub> SO <sub>4</sub> . 24H <sub>2</sub> O.	Coagulant.....	400-lb bbls..... 100-lb bags	39+	0.3 to 6.0.....	5.7 to 8.0..	Use generally restricted to chemical baskets where its slow solubility is an asset. Rate of solubility dependent upon acid requirement of the water.
Ferric chloride FeCl <sub>3</sub> .	Coagulant.....	110-lb drums containing one-pound packages of 95% anhydrous ferric chloride in plastic bags. 200-lb bags..... 400-lb bbls bulk	53+	0.5 to 3.0..... (average: 2 gpg).	3.5 to 9.5..	Very corrosive when in solution. Rubber-lined equipment must be used.
Soda ash Na <sub>2</sub> CO <sub>3</sub> .	To adjust pH or remove permanent hardness. Used in conjunction with ammonium alum.		63+	0.1 to 2.0 for pH adjustment. For permanent hardness removal; dose varies with hardness.		Readily soluble and non-corrosive to wrought-iron piping. May be used to prevent corrosion when hardness of water exceeds about 40 ppm.
Calcium Carbonate CaCO <sub>3</sub> .	To adjust pH. Used in conjunction with FeCl <sub>3</sub> ; provides nuclei for formation of floc.	80-lb bags.....	80	As needed to react with FeCl <sub>3</sub> dosage—approximately 3 gpg.	.....	Practically insoluble; kept in suspension by mechanical means.

Table IX. Alum Dosages and Corresponding Water Levels in Measuring Cup

Alum dosage in 3,000 gallons of water (grains per gallon)	Water level in cup (ounces)
4.....	33
3.....	29
2.....	24.5
1.....	20
Initial water level.....	16

Table X. Soda Ash Dosages and Corresponding Water Levels in Measuring Cup

Soda ash dosage in 3,000 gallons of water (grains per gallon)	Water level in cup (ounces)
4.....	27.5
3.....	24.5
2.....	22
1.....	19
Initial water level.....	16

Table XI. Decontamination of Significant Toxic Chemical Agents

Toxic chemical agents	Symbol	Physiological effect	Decontamination method	Allowable Period of consumption	Allowable concentration (ppm)
Nitrogen Mustards.....	HN-1 HN-2 HN-3	Blister gases.....	Activated carbon, 600 ppm...	1 week.....	5
Mustard.....	HD	Blister gas.....	.....do.....	.....do.....	5
Lewisite.....	L	.....do.....	.....do.....	.....do.....	20
Hydrogen Cyanide.....	AC	Blood gas.....	Warm water-aeraytion..... Cold water— 1. Superhypo- chlorina- tion, 100 ppm 2. Dechlorina- tion, 600 ppm car- bon	.....do.....	25
Nerve Agents.....	GA GB GD VX	Nerve gases.....	1. Superhypo- chlorina- tion 100 ppm 2. Dechlorina- tion, 600 ppm car- bon	3 days .....do.....	2 0.5

*Table XII. Table of International Atomic Weights*

Name	Symbol	Atomic number	Atomic weight
Actinium.....	Ac	89	227
Aluminum.....	Al	13	26.98
Americium.....	Am	95	243 *
Antimony.....	Sb	51	121.76
Argon.....	A	18	39.944
Arsenic.....	As	33	74.91
Astatine.....	At	85	210 *
Barium.....	Ba	56	137.36
Berkelium.....	Bk	97	249 *
Beryllium.....	Be	4	9.013
Bismuth.....	Bi	83	209.00
Boron.....	B	5	10.82
Bromine.....	Br	35	79.916
Cadmium.....	Cd	48	112.41
Calcium.....	Ca	20	40.08
Californium.....	Cf	98	251 *
Carbon.....	C	6	12.011
Cerium.....	Ce	58	140.13
Cesium.....	Cs	55	132.91
Chlorine.....	Cl	17	35.457
Chromium.....	Cr	24	52.01
Cobalt.....	Co	27	58.94
Copper.....	Cu	29	63.54
Curium.....	Cm	96	247 *
Dysprosium.....	Dy	66	162.51
Einsteinium.....	E	99	254 *
Erbium.....	Er	68	167.27
Europium.....	Eu	63	152.0
Fermium.....	Fm	100	253 *
Fluorine.....	F	9	19.00
Francium.....	Fr	87	223 *
Gadolinium.....	Gd	64	157.26
Gallium.....	Ga	31	69.72
Germanium.....	Ge	32	72.60
Gold.....	Au	79	197.0
Hafnium.....	Hf	72	178.50
Helium.....	He	2	4.00
Holmium.....	Ho	67	164.94
Hydrogen.....	H	1	1.008
Indium.....	In	49	114.82
Iodine.....	I	53	126.91
Iridium.....	Ir	77	192.2
Iron.....	Fe	26	55.85
Krypton.....	Kr	36	83.80
Lanthanum.....	La	57	138.92
Lead.....	Pb	82	207.21
Lithium.....	Li	3	6.940
Lutetium.....	Lu	71	174.99
Magnesium.....	Mg	12	24.32
Manganese.....	Mn	25	54.94
Mendelevium.....	Mv	101	256 *
Mercury.....	Hg	80	200.61

Table XII. Table of International Atomic Weights—Continued

Name	Symbol	Atomic number	Atomic weight
Molybdenum.....	Mo	42	95.95
Neodymium.....	Nd	60	144.27
Neon.....	Ne	10	20.183
Neptunium.....	Np	93	237 *
Nickel.....	Ni	28	58.71
Niobium.....	Nb	41	92.91
Nitrogen.....	N	7	14.008
Nobelium.....	No	102	253 *
Osmium.....	Os	76	190.2
Oxygen.....	O	8	16.000
Palladium.....	Pd	46	106.4
Phosphorus.....	P	15	30.975
Platinum.....	Pt	78	195.09
Plutonium.....	Pu	94	242 *
Polonium.....	Po	84	210
Potassium.....	K	19	39.100
Praseodymium.....	Pr	59	140.92
Promethium.....	Pm	61	147 *
Protactinium.....	Pa	91	231
Radium.....	Ra	88	226.05
Radon.....	Rn	86	222
Rhenium.....	Re	75	186.22
Rhodium.....	Rh	45	102.91
Rubidium.....	Rb	37	85.48
Ruthenium.....	Ru	44	101.1
Samarium.....	Sm	62	150.35
Scandium.....	Sc	21	44.96
Selenium.....	Se	34	78.96
Silicon.....	Si	14	28.09
Silver.....	Ag	47	107.880
Sodium.....	Na	11	22.991
Strontium.....	Sr	38	87.63
Sulfur.....	S	16	32.066
Tantalum.....	Ta	73	180.95
Technetium.....	Tc	43	99 *
Tellurium.....	Te	52	127.61
Terbium.....	Tb	65	158.93
Thallium.....	Tl	81	204.39
Thorium.....	Th	90	232.05
Thulium.....	Tm	69	168.94
Tin.....	Sn	50	118.70
Titanium.....	Ti	22	47.90
Tungsten.....	W	74	183.86
Uranium.....	U	92	238.07
Vanadium.....	V	23	50.95
Xenon.....	Xe	54	131.30
Ytterbium.....	Yb	70	173.04
Yttrium.....	Y	39	88.92
Zinc.....	Zn	30	65.38
Zirconium.....	Zr	40	91.22

\* The mass number of the most stable isotope.



*Table XIII. Molecular and Equivalent Weights*

Compound	Formula	Molecular weight	Equivalent weight
Acetic acid.....	$\text{CH}_3\text{COOH}$	60.05	60.05
Alum, ammonium.....	$\text{Al}_2(\text{SO}_4)_3 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 24\text{H}_2\text{O}$	906.69	151.12
Alum, crystals.....	$\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$	666.45	111.08
Alum, potassium.....	$\text{Al}_2(\text{SO}_4)_3 \cdot \text{K}_2\text{SO}_4 \cdot 24\text{H}_2\text{O}$	948.81	158.14
Aluminum.....	$\text{Al}$	26.98	8.99
Aluminum hydroxide.....	$\text{Al}(\text{OH})_3$	77.99	26.00
Aluminum oxide.....	$\text{Al}_2\text{O}_3$	101.94	16.99
Aluminum sulfate.....	$\text{Al}_2(\text{SO}_4)_3$	342.14	57.02
Ammonia.....	$\text{NH}_3$	17.03	17.03
Ammonium chloride (sal ammoniac)	$\text{NH}_4\text{Cl}$	53.50	53.50
Ammonium hydroxide.....	$\text{NH}_4\text{OH}$	35.05	35.05
Ammonium nitrate.....	$\text{NH}_4\text{NO}_3$	80.05	80.05
Ammonium oxalate.....	$(\text{NH}_4)_2\text{C}_2\text{O}_4$	124.10	62.05
Ammonium oxalate, crystals	$(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$	142.12	71.06
Ammonium sulphate.....	$(\text{NH}_4)_2\text{SO}_4$	132.15	66.08
Barium carbonate.....	$\text{BaCO}_3$	197.37	98.68
Barium chloride.....	$\text{BaCl}_2$	208.27	104.14
Barium chloride, crystals...	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	244.31	122.15
Barium sulfate (barium white)	$\text{BaSO}_4$	233.43	116.72
Boric acid.....	$\text{H}_3\text{BO}_3$	61.84	
Bromine.....	$\text{Br}_2$	159.83	79.92
Calcium bicarbonate.....	$\text{Ca}(\text{HCO}_3)_2$	162.12	81.06
Calcium carbonate (limestone)	$\text{CaCO}_3$	100.09	50.04
Calcium chloride.....	$\text{CaCl}_2$	110.99	55.50
Calcium hydroxide (slaked lime)	$\text{Ca}(\text{OH})_2$	74.10	37.05
Calcium oxalate.....	$\text{CaC}_2\text{O}_4$	128.10	64.05
Calcium oxide (quicklime)	$\text{CaO}$	56.08	28.04
Calcium sulfate (gypsum)...	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	172.18	86.09
Calcium sulfate (Plaster of Paris).....	$\text{CaSO}_4$	136.15	68.08
Carbon dioxide.....	$\text{CO}_2$	44.01	
Chlorine.....	$\text{Cl}_2$	70.91	35.45
Copper sulfate.....	$\text{CuSO}_4$	159.61	79.80
Copper sulfate (blue vitriol)	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	249.69	124.84
Ferric chloride.....	$\text{FeCl}_3$	162.22	54.07
Ferric chloride, crystals....	$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	270.32	90.11
Ferric hydroxide.....	$\text{Fe}(\text{OH})_3$	106.88	35.63
Ferric oxide.....	$\text{Fe}_2\text{O}_3$	159.70	26.62
Ferric sulfate.....	$\text{Fe}_2(\text{SO}_4)_3$	399.90	66.65
Ferric sulfate, crystals.....	$\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$	562.04	93.68
Ferric sulfocyanate.....	$\text{Fe}(\text{CNS})_3$	230.10	76.70
Ferrous ammonium sulfate..	$\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	392.17	196.07

*Table XIII. Molecular and Equivalent Weights—Continued*

Compound	Formula	Molecular weight	Equivalent weight
Ferrous carbonate.....	FeCO <sub>3</sub>	115.86	57.93
Ferrous hydroxide.....	Fe(OH) <sub>2</sub>	89.87	44.94
Ferrous sulfate.....	FeSO <sub>4</sub>	151.90	75.95
Ferrous sulfate, crystals (copperas).....	FeSO <sub>4</sub> ·7H <sub>2</sub> O	278.03	139.02
Hydrochloric acid (muriatic acid).....	HCl	36.47	36.47
Hydrogen.....	H <sub>2</sub>	2.016	1.008
Hydrogen sulfide.....	H <sub>2</sub> S	34.08	17.04
Iodine.....	I <sub>2</sub>	253.82	126.91
Magnesium ammonium phosphate.....	MgNH <sub>4</sub> PO <sub>4</sub>	137.34	
Magnesium bicarbonate....	Mg(HCO <sub>3</sub> ) <sub>2</sub>	146.36	73.18
Magnesium carbonate (mag- nesite).....	MgCO <sub>3</sub>	84.33	42.16
Magnesium chloride.....	MgCl <sub>2</sub>	95.23	47.62
Magnesium hydroxide (milk of magnesia).....	Mg(OH) <sub>2</sub>	58.34	29.17
Magnesium nitrate.....	Mg(NO <sub>3</sub> ) <sub>2</sub>	148.34	74.17
Magnesium oxide.....	MgO	40.32	20.16
Magnesium pyrophosphate .	Mg <sub>2</sub> P <sub>2</sub> O <sub>7</sub>	222.60	
Magnesium sulfate.....	MgSO <sub>4</sub>	120.39	60.20
Magnesium sulfate, crys- tals (Epsom salts).....	MgSO <sub>4</sub> ·7H <sub>2</sub> O	246.50	123.24
Manganic oxide.....	Mn <sub>2</sub> O <sub>3</sub>	157.86	26.31
Manganous oxide.....	MnO	70.93	35.47
Manganous sulfate.....	MnSO <sub>4</sub>	151.00	75.50
Manganous sulfate, crystals	MnSO <sub>4</sub> ·4H <sub>2</sub> O	223.06	111.53
Methane.....	CH <sub>4</sub>	16.03	
Molybdic acid.....	H <sub>2</sub> MoO <sub>4</sub>	161.97	
Nitric acid.....	HNO <sub>3</sub>	63.02	63.02
Oxalic acid.....	H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	90.02	45.01
Oxalic acid, crystals.....	H <sub>2</sub> C <sub>2</sub> O <sub>4</sub> ·2H <sub>2</sub> O	126.05	63.02
Oxygen.....	O <sub>2</sub>	32.00	8.00
Phosphoric acid.....	P <sub>3</sub> PO <sub>4</sub>	98.00	32.67
Phosphoric pentoxide.....	P <sub>2</sub> O <sub>5</sub>	141.96	
Platinic chloride.....	PtCl <sub>4</sub>	337.06	84.76
Potassium biniodate.....	KIO <sub>3</sub> ·HIO <sub>3</sub>	389.94	32.50
Potassium bromate.....	KBrO <sub>3</sub>	167.01	167.01
Potassium carbonate.....	K <sub>2</sub> CO <sub>3</sub>	138.20	69.10
Potassium chloride.....	KCl	74.55	74.55
Potassium chloroplatinate...	K <sub>2</sub> PtCl <sub>5</sub>	486.16	
Potassium chromate.....	K <sub>2</sub> CrO <sub>4</sub>	194.20	
Potassium cyanide.....	KCN	65.11	65.11
Potassium dichromate.....	K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	294.21	49.04*
Potassium ferricyanide....	K <sub>3</sub> Fe(CN) <sub>6</sub>	329.25	
Potassium hydroxide (caus- tic potash).....	KOH	56.10	56.10
Potassium iodide.....	KI	166.02	166.02
Potassium permanganate...	KMnO <sub>4</sub>	158.03	31.61*

\* Oxidation and reduction in acid medium.

Table XIII. Molecular and Equivalent Weights—Continued

Compound	Formula	Molecular weight	Equivalent weight
Potassium nitrate (salt-peter).....	$\text{KNO}_3$	101.10	101.10
Potassium oxalate, crystals..	$\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$	184.23	92.12
Potassium oxide.....	$\text{K}_2\text{O}$	94.19	47.10
Potassium sulfate.....	$\text{K}_2\text{SO}_4$	174.26	87.13
Potassium thiocyanate.....	$\text{KCNS}$	97.18	97.18
Silicon dioxide (silica).....	$\text{SiO}_2$	60.06	
Silver chloride.....	$\text{AgCl}$	143.34	143.34
Silver chromate.....	$\text{Ag}_2\text{CrO}_4$	331.77	
Silver nitrate.....	$\text{AgNO}_3$	169.89	169.89
Silver nitrite.....	$\text{AgNO}_2$	153.89	76.94
Silver sulfate.....	$\text{Ag}_2\text{SO}_4$	311.82	155.91
Sodium bicarbonate (baking soda).....	$\text{NaHCO}_3$	84.02	84.02
Sodium carbonate, anhydrous (soda ash).....	$\text{Na}_2\text{CO}_3$	106.00	53.00
Sodium carbonate (soda).....	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$	286.16	143.08
Sodium chloride (common salt).....	$\text{NaCl}$	58.45	58.45
Sodium hydroxide (caustic soda).....	$\text{NaOH}$	40.01	40.01
Sodium hypochlorite.....	$\text{NaOCl}$	74.45	
Sodium nitrate (Chile salt-peter).....	$\text{NaNO}_3$	85.01	85.01
Sodium oxalate.....	$\text{Na}_2\text{C}_2\text{O}_4$	134.01	67.00
Sodium phosphate, mono....	$\text{NaH}_2\text{PO}_4$	119.98	59.99
Sodium phosphate, di.....	$\text{Na}_2\text{HPO}_4$	141.96	141.96
Sodium phosphate, tri.....	$\text{Na}_3\text{PO}_4$	163.95	54.65
Sodium sulfate.....	$\text{Na}_2\text{SO}_4$	142.06	71.03
Sodium sulfate (Glauber's salt).....	$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$	322.22	161.11
Sodium thiosulfate (hypo)...	$\text{Na}_2\text{S}_2\text{O}_3$	158.13	158.13
Sodium thiosulfate, crystals..	$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	248.21	248.21
Sulfuric acid (oil of vitriol)...	$\text{H}_2\text{SO}_4$	98.08	49.04
Sulfurous acid.....	$\text{H}_2\text{SO}_3$	82.08	41.04
Water.....	$\text{H}_2\text{O}$	18.02	

Table XIV. Chemical Reactions in Water Purification

1. Alum and lime:  

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca}(\text{OH})_2 = 2\text{Al}(\text{OH})_3 + 3\text{CaSO}_4$$
2. Alum and soda ash:  

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Na}_2\text{CO}_3 + 3\text{H}_2\text{O} = 2\text{Al}(\text{OH})_3 + 3\text{Na}_2\text{SO}_4 + 3\text{CO}_2$$
3. Alum and alkalinity:  

$$\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca}(\text{HCO}_3)_2 = 2\text{Al}(\text{OH})_3 + 3\text{CaSO}_4 + 6\text{CO}_2$$
4. Ferric chloride and limestone (Erdlator):  

$$2\text{FeCl}_3 + 3\text{CaCO}_3 + 3\text{H}_2\text{O} = 2\text{Fe}(\text{OH})_3 + 3\text{CaCl}_2 + 3\text{CO}_2$$
5. Ferrous sulfate and lime:  

$$(a) \text{FeSO}_4 + \text{Ca}(\text{OH})_2 = \text{Fe}(\text{OH})_2 + \text{CaSO}_4$$

In the presence of dissolved oxygen,

$$(b) 2\text{Fe}(\text{OH})_2 + \text{H}_2\text{O} + \text{O} = 2\text{Fe}(\text{OH})_3$$
6. Hypochlorite of lime in water:  

$$(a) \text{Ca}(\text{OCl})_2 + \text{H}_2\text{O} + \text{CO}_2 = 2\text{HOCl} + \text{CaCO}_3$$

$$(b) \text{HOCl} = \text{H}^+ + \text{OCl}^-$$
7. Chlorine in water:  

$$(a) \text{Cl}_2 + \text{H}_2\text{O} = \text{HOCl} + \text{HCl}$$

$$(b) \text{HOCl} = \text{H}^+ + \text{OCl}^-$$
8. Chlorine and ammonia in water:  

$$(a) \text{Cl}_2 + \text{H}_2\text{O} = \text{HCl} + \text{HOCl}$$

$$(b) \text{HOCl} + \text{NH}_3 = \text{NH}_2\text{Cl} + \text{H}_2\text{O} \text{ (at pH 8.5)}$$

$$(c) 2\text{HOCl} + \text{NH}_3 = \text{NHCl}_2 + 2\text{H}_2\text{O} \text{ (at pH 4.5)}$$

$$(d) 3\text{HOCl} + \text{NH}_3 = \text{NCl}_3 + 3\text{H}_2\text{O} \text{ (below pH 4.4)}$$
9. Corrosion control:  

$$(1) \text{Fe} + 2\text{HOH} = \text{Fe}(\text{OH})_2 + \text{H}_2$$

$$(1a) \text{H}_2 + \text{O} = \text{H}_2\text{O}$$

$$(1b) 2\text{Fe}(\text{OH})_2 + \text{H}_2\text{O} + \text{O} = 2\text{Fe}(\text{OH})_3$$

$$(2) \text{Fe} + 2\text{H}_2\text{CO}_3 = \text{Fe}(\text{HCO}_3)_2 + \text{H}_2$$

$$(2a) \text{H}_2 + \text{O} = \text{H}_2\text{O}$$

$$(2b) 2\text{Fe}(\text{HCO}_3)_2 + \text{H}_2\text{O} + \text{O} = 2\text{Fe}(\text{OH})_3 + 4\text{CO}_2$$

#### WATER-SOFTENING REACTIONS

10. Lime and carbon dioxide:  

$$(a) \text{Ca}(\text{OH})_2 + 2\text{CO}_2 = \text{Ca}(\text{HCO}_3)_2$$

$$(b) \text{Ca}(\text{OH})_2 + \text{H}_2\text{O} + \text{CO}_2 = \text{CaCO}_3 + 2\text{H}_2\text{O}$$
11. Bicarbonate hardness and lime:  

$$\text{Ca}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 = 2\text{CaCO}_3 + 2\text{H}_2\text{O}$$
12. Magnesium carbonate and lime:  

$$\text{MgCO}_3 + \text{Ca}(\text{OH})_2 = \text{Mg}(\text{OH})_2 + \text{CaCO}_3$$
13. Magnesium sulfate and lime:  

$$\text{MgSO}_4 + \text{Ca}(\text{OH})_2 = \text{Mg}(\text{OH})_2 + \text{CaSO}_4$$
14. Soda ash and calcium sulfate:  

$$\text{CaSO}_4 + \text{Na}_2\text{CO}_3 = \text{CaCO}_3 + \text{Na}_2\text{SO}_4$$
15. Zeolite and hardness:  

Let Z represent zeolite:

$$2\text{NaZ} + \text{CaSO}_4 = \text{CaZ} + \text{Na}_2\text{SO}_4$$
16. Calcium zeolite and salt:  

$$\text{CaZ} + 2\text{NaCl} = \text{NaZ} + \text{CaCl}_2$$

Table XV. Conversion Factors

### DISTANCE

Inch=	2.54	centimeters
Foot=	30.48	centimeters
Yard=	91.44	centimeters
Mile=	5,280.0	feet
Mile=	1.609	kilometers
Meter=	3.28	feet
Meter=	39.37	inches

### AREA

Square inch=	6.45	square centimeters
Square foot=	144.0	square inches
Acre=	43,560.0	square feet
Acre=	4,047.0	square meters
Square mile=	640.0	acres

### WEIGHT

Grain=	0.0648	grams
Ounce (Avoirdupois)=	437.5	grains
Ounce=	28.35	grams
Ounce (troy or av.)=	480.0	grains
Ounce (troy)=	31.1035	grams
Pound (avoirdupois)=	7,000.0	grains
Pound=	453.59	grams
Pound (Troy)=	5,760.0	grains
Pound=	373.24	grams
Gram=	15.4324	grains
Kilogram=	2.2046	pounds av

### VOLUME

Cubic inch=	16.387	cubic centimeters
Cubic foot=	28,317	cubic centimeters
Cubic foot=	1,728.0	cubic inches
Cubic foot=	28.317	liters
Cubic yard=	27.0	cubic feet
Cubic centimeter=	0.99997	milliliter

### LIQUID CAPACITY

Fluid ounce=	29.57	milliliters
Pint=	16.0	fluid ounces
Pint=	473.167	milliliters
Pint=	28.875	cubic inches
Quart=	0.946	liter
Gallon=	3.785	liters
Gallon=	231.0	inches
Milliliter=	16.23	minims
Milliliter=	0.061	cubic inch
Liter=	1.0567	liquid quarts
Liter=	1,000.0	milliliters
Liter=	61.025	cubic inches
Cubic inch=	266	minims
Cubic inch=	16.387	milliliters

Table XV. Conversion Factors—Continued

CONSTANTS AND EQUIVALENTS

Atmosphere=	14.7	pounds per square inch (sea level)
Pound per square inch=	2.0376	inches of mercury
Pound per square inch=	2.307	feet of water
Pound per square inch=	27.71	inches of water
Pound per square inch=	0.0703	Kilogram per square centimeter
Foot of water=	0.433	pound per square inch
Inch of mercury=	0.491	pound per square inch
Inch of mercury=	1.132	feet of water
Horsepower=	33,000.0	foot-pounds per minute
Horsepower=	0.746	kilowatt
Water horsepower=	$\frac{\text{gallons per minute} \times \text{head in feet}}{3,960}$	
Kilowatt=	1.3405	horsepower
Efficiency=	$\frac{\text{water horsepower}}{\text{brake horsepower}}$	
Cubic foot of water weighs 62.355 pounds at 62° F.		
Gallon of water weighs 8.355 pounds at 62° F.		
US gallon=3.785 liters		
Cubic foot of water=7.48 US gallons		
Imperial gallon=1.2 US gallons		
Velocity head h=	$\frac{V^2}{2g}$	
	g=32.16 feet per second	

MISCELLANEOUS DATA

Railroad Tender Capacity—Normal 5,000 gal—Maximum 20,000 gal
Track Storage Tanks—25,000 to 50,000 gal
Railroad Water Supply Points—Spacing—10 to 15 miles
Tank Car Capacity—Standard Commercial— 8,000 to 10,000 gal
— 5,000 gal
Tank Truck Capacity—Military—1,500 gal (semitrailer)
700 gal (truck)
250 gal (trailer)

Table XVI. Flow of Water (GPM) Through Smooth-Bore Hose

Hose (internal diameter inches)	Pounds per square inch									
	20	30	40	50	60	70	80	90	100	125
1.00.....	23	28	33	37	40	43	46	49	52	58
1.25.....	40	50	57	64	70	76	81	86	90	101
1.50.....	64	78	90	101	111	120	128	135	143	159
2.00.....	130	159	184	206	227	242	262	275	292	326
2.50.....	226	278	322	358	394	425	455	482	509	566
3.00.....	356	437	504	570	620	665	715	755	800	890
4.00.....	745	910	1,055	1,180	1,292	1,395	1,492	1,582	1,670	1,850

Note. This table is based on 100-foot length of hose, laid in a straight line with open discharge end. For each set of couplings, deduct 5 percent.

*Table XVII. Suction Lift of Pumps at Various Altitudes*

Altitude above sea level		Barometric pressure (pounds per sq in.)	Equivalent head of water (feet)	Practical suction lift of pump (feet)
Feet	Miles			
0.....	0	14.70	33.95	25
1,320.....	$\frac{1}{4}$	14.02	32.38	24
2,640.....	$\frac{1}{2}$	13.33	30.79	23
3,960.....	$\frac{3}{4}$	12.66	29.24	21
5,280.....	1	12.02	27.76	20
6,600.....	$1\frac{1}{4}$	11.42	26.38	19
7,920.....	$1\frac{1}{2}$	10.88	25.13	18
10,560.....	2	9.88	22.82	17

*Table XVIII. Flow of Vertical Jets in Gallons Per Minute*

Height of jet (inches)	Diameter of pipe or hose (inches)			
	1	$1\frac{1}{2}$	2	3
$\frac{1}{2}$ .....	3.96	8.9	15.6	35.6
1.....	5.60	12.6	22.4	50.4
2.....	7.99	18.0	32.0	71.9
4.....	11.3	25.4	45.3	102
6.....	13.9	31.3	55.5	125
8.....	16.0	36.0	64.0	144
10.....	17.9	40.3	71.6	161
15.....	22.0	49.5	87.8	198
20.....	25.4	57.2	102	228
30.....	30.9	69.5	123	278
60.....	43.8	98.6	175	394
108.....	58.9	132.5	236	531
144.....	68.0	153.0	272	612

Table XIX. Discharge of Water From Full-Flowing Horizontal Pipes  
(fig. 90)

Note. Jet must be full-flowing + no contraction or enlargement.

$$\text{Flow in gpm} = \frac{2.83 D^2 X}{\sqrt{Y}}$$

$D$  = Inside diameter of pipe

$X$  = Horizontal distance in inches

$Y$  = Vertical distance in inches

Example, using formula:

Given: A 3-inch diameter standard pipe ( $D=3.07''$ ) held 16 inches from ground ( $Y=16''$ ).  $X$  determined by measurement ( $X=28''$ ).

$$\frac{2.83 \times 3.07^2 \times 28}{\sqrt{16}} = \frac{2.83 \times 9.4 \times 28}{4} = 187 \text{ gpm}$$

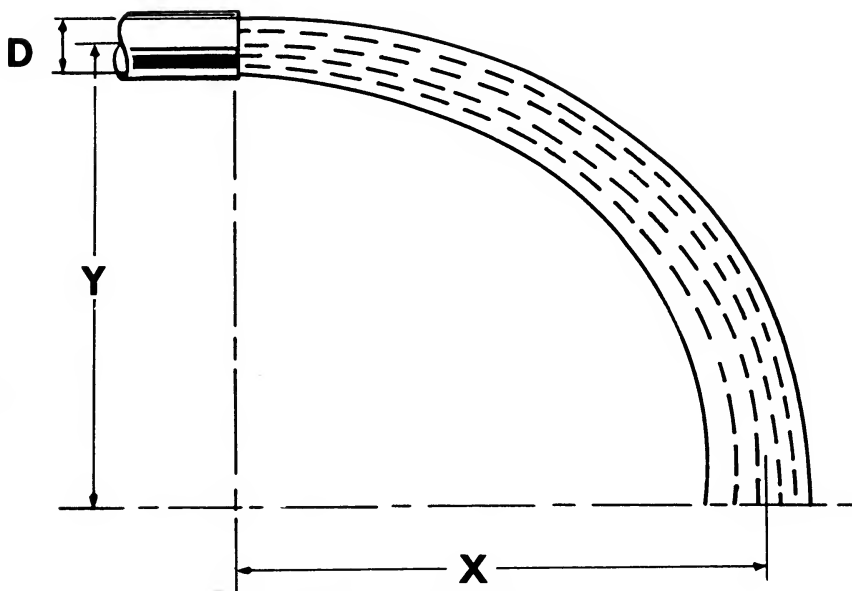


Figure 90. Discharge of water from horizontal pipe.



Table XIX. Discharge of Water From Full-Flowing Horizontal Pipes (fig. 90)  
 —Continued

Note. Table below is based on Y=12". When table does not apply, measure Y at 9", 16", or 25" for simplicity in taking square root.

GPM FOR Y=12" AND VARIOUS VALUES OF X

Distance X =	8'	10'	12'	14'	16'	18'	20'	22'	24'	26'
D = 1.61"										
1½" ø Std pipe.....	17	21	25	30	34	38	42	47	51	55
D = 2.07"										
2" ø Std pipe.....	28	35	42	49	56	63	70	77	84	91
D = 4.03"										
4" ø Std pipe.....	106	132	159	185	212	238	265	291	318	344

Distance X =	28'	30'	32'	34'	36'	38'	40'	42'	44'	46'	48'
D = 1.61"											
1½" ø Std pipe.....	59	64	68	72	76	80	85	89	93	97	102
D = 2.07"											
2" ø Std pipe.....	98	105	112	119	126	133	140	147	154	160	167
D = 4.03"											
4" ø Std pipe.....	371	397	424	450	477	503	530	556	583	609	656

Table XX. Rate of Flow Equivalents

Units	Cubic feet per second	Cubic feet per minute	US gallons per minute	US gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cu ft per sec.	1.0	60.0	448.831	646,317.0	373.729	1,698.98	0.082645	1.98347
1 cu ft per min.	.016667	1.0	7.48052	10,771.9	6.22882	28.3163	.0013774	.033058
1 US gal per min.	.0022280	.13368	1.0	1,440.0	.83267	3.78533	.0001841	.0044192
1 US gal per 24 hr.	1.547×10 <sup>-6</sup>	9.283×10 <sup>-3</sup>	.0006944	1.0	.0005782	.0026287	.279×10 <sup>-7</sup>	3.069×10 <sup>-8</sup>
1 British Imperial gal per min.	.0026757	.16054	1.20095	1,729.37	1.0	4.54601	.0002211	.0053072
1 liter per min.	.0005886	.035315	.26418	380.416	0.21997	1.0	4.864×10 <sup>-8</sup>	.001167
1 acre-ft per hr.	12.1	726.0	5,430.86	7,820,434.0	4,522.13	20,557.6	1.0	24.0
1 acre-ft per 24 hr.	.50417	30.25	226.286	325,851.0	188.422	856.567	.041667	1.0

Table XXI. Volume and Capacity Equivalents

Units	US gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 US gallon	1.0	0.832672	3.78533	0.133681	231.0	3.069×10 <sup>-6</sup>
1 British Imperial gallon	1.20095	1.0	4.54601	.180544	277.420	3.686×10 <sup>-6</sup>
1 liter	.264177	.219973	1.0	.035315	61.0250	8.107×10 <sup>-7</sup>
1 cubic foot	7.48052	6.22882	28.3163	1.0	1,728.0	2.296×10 <sup>-5</sup>
1 cubic inch	4.329×10 <sup>-5</sup>	3.605×10 <sup>-5</sup>	.016387	5.787×10 <sup>-4</sup>	1.0	1.329×10 <sup>-8</sup>
1 acre-foot	325,851.0	271,328.0	1,233,456.0	43,560.0	75,271,680.0	1.0
1 inch deep on 1 acre	27,154.3	22,610.6	102,788.0	3,630.0	6,272,640.0	.0833333
1 inch deep on 1 square mile	17,378,743.0	14,470,801.0	65,784,344.0	2,353,200.0	4,014,489,600.0	53.3533
1 meter deep on 1 hectare	2,631,705.0	2,199,675.0	9,999,734.0	353,145.0	610,233,780.0	8.10708
1 centimeter deep on 1 square meter	2.64171	2.19977	9.99973	.353145	610.234	8.107×10 <sup>-6</sup>
1 pound of water at 39.2° F.	.11983	.099778	.45349	.016019	27.6805	3.677×10 <sup>-7</sup>
1 pound of water at 50° F.	.11986	.099806	.45372	.016023	27.6880	3.678×10 <sup>-7</sup>
1 pound of water at 62° F.	.11997	.099892	.45411	.016037	27.7121	3.682×10 <sup>-7</sup>
1 US gallon per minute for 24 hours	1,440.0	1,199.05	5,450.88	192.5	332,640.0	.0044192
1 cubic foot per minute for 24 hours	10,771.9	8,969.50	40,775.4	1,440.0	2,488,320.0	.033058

Table XXII. Pressure Equivalents

Units	Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch.....	1.0	144.0	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot.....	.00694444	1.0	.0004882	.014139	.016019	.016037	.0004725
1 ounce per square inch.....	.0625	9.0	.0043942	.12725	.14469	.0144334	.002528
1 kilogram per square centimeter.....	14.2234	2,048.17	1.0	28.9582	32.8082	32.8467	.967820
1 kilogram per square meter.....	.0014223	.204817	.0001	.0028958	.0032809	.0032847	9.678X10 <sup>-8</sup>
1 inch of mercury at 32° F.....	.49117	70.7285	.034533	1.0	1.13299	1.13428	.033421
1 inch of water at 39.2° F.....	.036127	5.20222	.0025399	.073552	.083333	.083428	.0024562
1 inch of water at 62° F.....	.036085	5.19628	.0025370	.073468	.083238	.083333	.0024554
1 foot of water at 39.2° F.....	.43352	62.4266	.030479	.88262	1.0	1.00114	.029498
1 foot of water at 62° F.....	.43302	62.3554	.030444	.88162	1.0	1.0	.029465
1 atmosphere.....	14.6963	2,116.27	1.03325	29.9210	33.9001	33.9388	1.0

Table XXIII. For Conversion of Pressure in PSI to Head in Feet of Water

Pressure in psi	Head in feet	Pressure in psi	Head in feet	Pressure in psi	Head in feet
0.1.....	0.23	33.....	76.2	75.....	173
0.2.....	.46	34.....	78.5		
0.3.....	.69	35.....	80.9	76.....	176
0.4.....	.92			77.....	178
0.5.....	1.16	36.....	83.2	78.....	180
		37.....	85.5	79.....	183
		38.....	87.8	80.....	185
0.6.....	1.39	39.....	90.1		
0.7.....	1.62	40.....	92.4	81.....	187
0.8.....	1.85			82.....	189
0.9.....	2.08	41.....	94.7	83.....	192
		42.....	97.0	84.....	194
1.....	2.31	43.....	99.3	85.....	196
2.....	4.62	44.....	102		
3.....	6.93	45.....	104	86.....	199
4.....	9.23			87.....	201
5.....	11.6	46.....	106	88.....	203
		47.....	109	89.....	206
6.....	13.9	48.....	111	90.....	208
7.....	16.2	49.....	113		
8.....	18.5	50.....	116	91.....	210
9.....	20.8			92.....	213
10.....	23.1	51.....	118	93.....	215
		52.....	120	94.....	217
11.....	25.4	53.....	122	95.....	219
12.....	27.7	54.....	125		
13.....	30.0	55.....	127	96.....	222
14.....	32.3			97.....	224
15.....	34.7	56.....	129	98.....	226
		57.....	132	99.....	229
16.....	37.0	58.....	134	100.....	231
17.....	39.3	59.....	136		
18.....	41.6	60.....	139	102.....	236
19.....	43.9			104.....	240
20.....	46.2	61.....	141	106.....	245
		62.....	143	108.....	249
21.....	48.5	63.....	146	110.....	254
22.....	50.8	64.....	148		
23.....	53.1	65.....	150	112.....	259
24.....	55.4			114.....	263
25.....	57.8	66.....	153	116.....	268
		67.....	155	118.....	273
26.....	60.1	68.....	157	120.....	277
27.....	62.4	69.....	159		
28.....	64.9	70.....	162	122.....	282
29.....	67.0			124.....	286
30.....	69.3	71.....	164	126.....	291
		72.....	166	128.....	296
31.....	71.6	73.....	169	130.....	300
32.....	73.9	74.....	171		

*Table XXIII. For Conversion of Pressure in PSI to Head in Feet of Water—Continued*

Pressure in psi	Head in feet	Pressure in psi	Head in feet	Pressure in psi	Head in feet
132.....	305	150.....	347	190.....	439
134.....	310			195.....	450
136.....	314	155.....	358	200.....	462
138.....	319	160.....	370		
140.....	323	165.....	381	220.....	508
		170.....	393	240.....	554
142.....	328	175.....	404	260.....	601
144.....	333			280.....	647
146.....	337	180.....	416	300.....	693
148.....	342	185.....	427		

*Table XXIV. For Conversion of Head of Water to PSI*

Head in feet	Pressure in psi	Head in feet	Pressure in psi	Head in feet	Pressure in psi
1.....	0.43	26.....	11.3	52.....	22.5
2.....	.86	27.....	11.7	54.....	23.4
3.....	1.30	28.....	12.1	56.....	24.3
4.....	1.73	29.....	12.6	58.....	25.1
5.....	2.16	30.....	13.0	60.....	26.0
6.....	2.59	31.....	13.4	62.....	26.9
7.....	3.03	32.....	13.9	64.....	27.7
8.....	3.46	33.....	14.3	66.....	28.6
9.....	3.89	34.....	14.7	68.....	29.5
10.....	4.33	35.....	15.2	70.....	30.3
11.....	4.76	36.....	15.6	72.....	31.2
12.....	5.20	37.....	16.0	74.....	32.1
13.....	5.63	38.....	16.5	76.....	32.9
14.....	6.06	39.....	16.9	78.....	33.8
15.....	6.49	40.....	17.3	80.....	34.7
16.....	6.93	41.....	17.8	82.....	35.5
17.....	7.36	42.....	18.2	84.....	36.4
18.....	7.79	43.....	18.6	86.....	37.3
19.....	8.22	44.....	19.1	88.....	38.1
20.....	8.66	45.....	19.5	90.....	39.0
21.....	9.09	46.....	19.9	92.....	39.9
22.....	9.53	47.....	20.4	94.....	40.7
23.....	10.0	48.....	20.8	96.....	41.6
24.....	10.4	49.....	21.2	98.....	42.5
25.....	10.8	50.....	21.7	100.....	43.3

Table XXIV. For Conversion of Head of Water to PSI—Continued

Head in feet	Pressure in psi	Head in feet	Pressure in psi	Head in feet	Pressure in psi
104.....	45.1	204.....	88.4	310.....	134
108.....	46.8	208.....	90.1	320.....	139
112.....	48.5	212.....	91.8	330.....	143
116.....	50.2	216.....	93.6	340.....	147
120.....	52.0	220.....	95.3	350.....	152
124.....	53.7	224.....	97.0	360.....	156
128.....	55.4	228.....	98.8	370.....	160
132.....	57.2	232.....	100	380.....	165
136.....	58.9	236.....	102	390.....	169
140.....	60.6	240.....	104	400.....	173
144.....	62.4	244.....	106	420.....	182
148.....	64.1	248.....	107	440.....	191
152.....	65.8	252.....	109	460.....	199
156.....	67.6	256.....	111	480.....	208
160.....	69.3	260.....	113	500.....	217
164.....	71.0	264.....	114	520.....	225
168.....	72.8	268.....	116	540.....	234
172.....	74.5	272.....	118	560.....	242
176.....	76.2	276.....	120	580.....	251
180.....	78.0	280.....	121	600.....	260
184.....	79.7	284.....	123	650.....	282
188.....	81.4	288.....	125	700.....	303
192.....	83.2	292.....	126	800.....	347
196.....	84.9	296.....	128	900.....	390
200.....	86.6	300.....	130	1,000.....	433

Table XXV. Friction of Water in Pipes

The friction head losses in pipes were derived using the William and Hazen coefficient of 100. This coefficient corresponds to 10-year-old steel or 18-year-old cast-iron pipe. To adjust the friction head loss for various types of pipe, use the factor below. For example: To find the friction head loss for 3-inch iron pipe with very rough inside surface, passing 50 gpm, find 13.8 feet per 1,000 feet of pipe in table and multiply by 2.58. Answer: 35.6 feet friction head loss per 1,000 feet of 3-inch iron pipe with very rough inside surface.

Kind of pipe:	Factor
New cast iron (straight) .....	0.540
New lead or brass .....	.540
New concrete or masonry (very smooth) .....	.540
New cast iron (not straight) .....	.615
Smooth concrete or masonry .....	.615
New wrought iron (smooth) .....	.715
Cast iron (5 years old) .....	.715
Wood (smooth) .....	.715
New rivet steel .....	.840
Vitrified sewer .....	.840
Cast iron (30 years old) .....	1.51
Old wrought iron .....	1.51
Small wrought iron (over 15 years old) .....	1.51
Iron with very rough inside surface .....	2.58

Gallons per minute	Millions of gallons per 24 hours	Velocity, feet per second	Velocity, head in feet	Friction in feet per 1,000 feet pipe
1½-inch pipe (1.61 inches inside dia)				
4.....	0.00576	0.63	0.01	2.6
6.....	.00864	0.94	.01	5.6
8.....	.0115	1.26	.02	9.5
10.....	.0144	1.57	.04	14.3
12.....	.01728	1.89	.05	20.1
14.....	.0202	2.20	.06	26.8
16.....	.0230	2.52	.10	34.1
20.....	.0288	3.15	.15	52.0
25.....	.0360	3.96	.24	78.0
30.....	.0432	4.72	.38	110
35.....	.0504	5.51	.47	147
40.....	.0576	6.30	.61	188
45.....	.0648	7.08	.77	232
50.....	.0720	7.87	.97	284
60.....	.0864	9.44	1.38	396

*Table XXV. Friction of Water in Pipes—Continued*

Gallons per minute	Millions of gallons per 24 hours	Velocity, feet per second	Velocity, head in feet	Friction in feet per 1,000 feet pipe
1½-inch pipe (1.61 inches inside dia)—continued				
70.....	.101	11.02	1.87	530
80.....	.115	12.59	2.48	680
90.....	.130	14.17	3.12	840
100.....	.144	15.74	3.84	1,020
120.....	.173	18.89	5.51	1,430
140.....	.202	22.04	7.60	1,900
2-inch pipe (2.00 inches inside dia)				
6.....	0.00864	0.61	0.01	2.0
10.....	.0144	1.02	.02	5.0
15.....	.0216	1.54	.04	10.8
20.....	.0288	2.04	.06	18.2
25.....	.0360	2.55	.10	27.3
30.....	.0432	3.06	.15	38.4
35.....	.0504	3.57	.20	51.0
40.....	.0576	4.08	.26	66.0
50.....	.0720	5.11	.40	99.0
60.....	.0864	6.13	.58	139
70.....	.101	7.15	.79	184
80.....	.115	8.17	1.04	237
90.....	.130	9.19	1.31	294
100.....	.144	10.21	1.62	358
120.....	.173	12.25	2.33	500
140.....	.202	14.30	3.17	670
160.....	.230	16.34	4.14	860
180.....	.259	18.38	5.23	1,070
200.....	.288	20.42	6.46	1,290
220.....	.316	22.47	7.82	1,540
240.....	.345	24.51	9.31	1,820
260.....	.374	26.55	10.90	2,110
3-inch pipe				
10.....	0.0144	0.45	0.00	0.7
15.....	.0216	.68	.01	1.5
20.....	.0288	.91	.01	2.5
30.....	.0432	1.36	.03	5.4
40.....	.0576	1.82	.05	9.1



Table XXV. *Friction of Water in Pipes*—Continued

Gallons per minute	Millions of gallons per 24 hours	Velocity, feet per second	Velocity, head in feet	Friction in feet per 1,000 feet pipe
3-inch pipe—continued				
50.....	.0720	2.27	.08	13.8
60.....	.0864	2.72	.12	19.2
70.....	.1008	3.18	.16	25.7
80.....	.1152	3.63	.20	32.8
90.....	.1296	4.09	.26	40.8
100.....	.1440	4.54	.32	49.6
120.....	.1728	5.45	.46	70.0
140.....	.2016	6.35	.63	92.0
160.....	.2304	7.26	.82	118
180.....	.2592	8.17	1.04	148
200.....	.2880	9.08	1.28	178
220.....	.3168	9.99	1.55	213
240.....	.3456	10.89	1.84	251
260.....	.3744	11.80	2.16	291
280.....	.4032	12.71	2.51	334
300.....	.4320	13.62	2.88	380
320.....	.4608	14.52	3.28	428
340.....	.4896	15.43	3.71	479
360.....	.5184	16.34	4.15	530
380.....	.5472	17.25	4.62	590
400.....	.5760	18.16	5.11	650
420.....	.6048	19.06	5.64	710
440.....	.6336	19.97	6.20	770
460.....	.6624	20.88	6.78	840
480.....	.6912	21.79	7.38	910
500.....	.7200	22.70	8.00	980
550.....	.7920	24.96	9.70	1,170
600.....	.8640	27.23	11.50	1,370

4-inch pipe

20.....	0.0288	0.51	0.00	0.62
30.....	.0432	.77	.01	1.32
40.....	.0576	1.02	.02	2.23
50.....	.0720	1.28	.03	3.39
60.....	.0864	1.53	.04	4.72
70.....	.1008	1.79	.05	6.3
80.....	.1152	2.04	.06	8.1
100.....	.1440	2.55	.10	12.2
120.....	.1728	3.06	.15	17.1
140.....	.2016	3.57	.20	22.8

*Table XXV. Friction of Water in Pipes—Continued*

Gallons per minute	Millions of gallons per 24 hours	Velocity, feet per second	Velocity, head in feet	Friction in feet per 1,000 feet pipe
4-inch pipe—continued				
160.....	.2304	4.08	.26	29.1
180.....	.2592	4.60	.33	36.1
200.....	.2880	5.11	.41	44.0
220.....	.3168	5.62	.49	52.0
240.....	.3456	6.13	.58	62.0
260.....	.3744	6.64	.69	72
280.....	.4032	7.15	.79	82
300.....	.4330	7.66	.91	93
320.....	.4608	8.17	1.04	105
340.....	.4896	8.68	1.17	117
360.....	.5184	9.19	1.31	131
400.....	.576	10.21	1.62	160
450.....	.648	11.49	2.05	198
500.....	.720	12.77	2.53	240
600.....	.864	15.32	3.65	337
700.....	1.008	17.87	4.96	449
800.....	1.152	20.42	6.48	570
900.....	1.296	22.98	8.20	710

Table XXVI. Resistance of Valves and Fittings

	Standard elbow	Medium-radius elbow	Long-radius elbow	45° elbow	Tee	Return bend	Gate valve open	Globe valve open	Angle valve open
Length of straight pipe giving equivalent resistance to flow									
1½"	1.5	1.4	1.1	.77	3.4	3.8	0.35	16	8.4
¾"	2.2	1.3	1.4	1.0	4.5	5.0	.47	22	12
1"	2.7	2.3	1.7	1.3	5.8	6.1	.6	27	15
1¼"	3.7	3.0	2.4	1.6	7.8	8.5	.8	37	18
1½"	4.3	3.6	2.8	2.0	9.0	10	.95	44	22
2"	5.5	4.6	3.5	2.5	11	13	1.2	57	28
2½"	6.5	5.4	4.2	3.0	14	15	1.4	66	33
3"	8.1	6.8	5.1	3.8	17	18	1.7	85	42
3½"	9.5	8.0	6.0	4.4	19	21	2.	99	50
4"	11	9.1	7.0	5.0	22	24	2.3	110	58
4½"	12	10	7.9	5.6	24	27	2.6	130	61
5"	14	12	8.9	6.1	27	31	2.9	140	70
6"	16	14	11	7.7	33	37	3.5	160	83
8"	21	18	14	10	43	49	4.5	220	100
10"	26	22	17	13	56	61	5.7	290	140
12"	32	26	20	15	66	73	6.7	340	170

## APPENDIX III

### FORMULAS FOR WATER SUPPLY PROBLEMS

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This appendix gives formulas for use in solving water supply problems frequently encountered in the field. Each formula is accompanied by an illustrative problem whose solution is found by use of the formula.

An acquaintance with these formulas, the problems, and their solutions, will greatly aid water supply personnel in their work in the field.

#### 1. Calculating Weight of Water

*a. Formula.*

(1)  $\text{Lb of H}_2\text{O} = \text{cu ft} \times 62.4$

(2)  $\text{Lb of H}_2\text{O} = \text{the weight of water}$

(3)  $\text{Cu ft} = \text{cubic feet or volume of container}$

(4)  $62.4 = \text{the weight (in pounds) of 1 cubic foot of water}$

*b. Illustrative Problem.* What is the weight of water present in a full tank that has a volume of 470 cubic feet?

$$\text{Lb of H}_2\text{O} = \text{cu ft} \times 62.4$$

$$= 470 \times 62.4$$

$$= 29,328 \text{ lb of water}$$

#### 2. Calculating Pressure of Water

*a. Formula.*

(1)  $\text{PSI} = \text{Vert ft of H}_2\text{O} \times 0.43$

(2)  $\text{PSI} = \text{pounds per square inch}$

(3)  $\text{Vert ft of H}_2\text{O} = \text{vertical feet of water}$

(4)  $0.43 = \text{the pressure (psi) exerted by 1 vertical foot of water.}$

*b. Illustrative Problem.* What is the pressure in pounds per square inch (psi) at the bottom of a storage tank that has 25 vertical feet of water present?

$$\text{PSI} = \text{vert ft of H}_2\text{O} \times 0.43$$

$$= 25 \times 0.43$$

$$= 10.75$$

### 3. Calculating Vertical Feet of Water

a. *Formula.*

(1)  $\text{Vert ft of H}_2\text{O} = \text{PSI} \times 2.3$  (see example 2)

(2) 2.3: It takes a column of water 2.3 feet high to cause a pressure of 1 pound per square inch.

b. *Illustrative Problem.* What is the vertical feet of water in an enclosed tank that is 45 feet high? A pressure gage at the bottom of the tank reads 9 psi.

$$\text{Vert ft of H}_2\text{O} = \text{PSI} \times 2.3$$

$$= 9 \times 2.3$$

$$= 20.7 \text{ vert ft of H}_2\text{O}$$

### 4. Calculating Gallons of Water

a. *Formula.*

(1)  $\text{Gal of H}_2\text{O} = \text{Cu ft} \times 7.5$

(2) Gal of H<sub>2</sub>O = gallons of water

(3) 7.5 = gallons of water in 1 cubic foot of water.

b. *Illustrative Problem.* How many gallons of water are present in a water tank that has a volume of 400 cubic feet?

$$\text{Gal of H}_2\text{O} = \text{Cu ft} \times 7.5$$

$$= 400 \times 7.5$$

$$= 3,000 \text{ gal of water}$$

### 5. Calculating Volume of Water Tanks

a. *Formula* (Rectangular tank).

(1)  $V = L \times W \times H$

(2) V = volume in cubic feet

(3) L = length in feet

(4) W = width in feet

(5) H = height in feet

b. *Formula* (Cylindrical tank).

(1)  $V = \pi r^2 H$

(2)  $\pi = 3.14$  or  $\frac{22}{7}$ , a constant—the relationship between the diameter and circumference of a circle.

(3)  $r^2$  = the radius (half of diameter) squared.

c. *Illustrative Problems.* What is the volume of a rectangular tank that has a length of 10 feet, a width of 7 feet, and a height of 4 feet?

$$V = L \times W \times H$$

$$= 10 \times 7 \times 4$$

$$= 280 \text{ cubic feet}$$

What is the volume of a cylindrical tank that has a radius of 4 feet and is 7 feet high?

$$\begin{aligned}
 V &= \pi r^2 H \\
 &= 3.14 \times 4^2 \times 7 \\
 &= 3.14 \times 16 \times 7 \\
 &= 351.68 \text{ cubic feet}
 \end{aligned}$$

## 6. Calculating Quantity of Water (GPM) Flowing In a Stream

### a. Formula.

$$(1) \quad Q = 6.4 \times A \times V$$

(2) Q=quantity of water in gallons per minute.

(3) 6.4=a constant—there are 7.5 gallons of water per cubic foot. However because of error in stream measurement 7.5 has been reduced to 6.4.

(4) V=the velocity of the stream in feet per minute. This is obtained by noting the time it takes a twig or floating object to travel a known distance.

(5) A=the area of the stream in square feet—obtained by multiplying the width of the stream times the depth of the stream.

*b. Illustrative Problem.* A stream has an average depth of 2 feet and a width of 16 feet, and a twig is noted to flow 13.3 feet per minute. How many gallons per minute are flowing in this stream?

$$\begin{aligned}
 Q &= 6.4 \times A \times V \\
 &= 6.4 \times 2 \times 16 \times 13.3 \\
 &= 2,723.84 \text{ gal per minute}
 \end{aligned}$$

## 7. Calculating Pounds of Chemical (Alum or Soda Ash)

### a. Formula.

$$(1) \quad \text{Lb of chem} = \frac{\text{gal of water} \times \text{GPG}}{7,000}$$

(2) Lb of chem=pounds of alum or soda ash.

(3) GPG=grains per gallon of alum or soda ash.

(4) 7,000=a constant, the number of grains in 1 pound of chemical.

*b. Illustrative Problems.* If 8 grains per gallon of alum and 3 grains per gallon of soda ash were used to treat 14,000 gallons of water, how many pounds of alum and soda ash would be required?

$$\begin{aligned}
 \text{Lb of chem} &= \frac{\text{gal} \times \text{GPG (alum)}}{7,000} \\
 &= \frac{14,000 \times 8}{7,000} \\
 &= 16 \text{ pounds of alum}
 \end{aligned}$$

$$\begin{aligned}
 \text{Lb of chem} &= \frac{\text{gal} \times \text{GPG (S.A.)}}{7,000} \\
 &= \frac{14,000 \times 3}{7,000} \\
 &= 6 \text{ pounds of soda ash}
 \end{aligned}$$

## 8. Calculating Gallons of Water That Can Be Treated With a Certain Supply of Alum and Soda Ash on Hand

a. *Formula.*

$$\text{Gal of water} = \frac{\text{lb of chem} \times 7,000}{\text{GPG}} \quad (\text{see example 7})$$

b. *Illustrative Problem.* There are 25 pounds of alum on hand; 10 grains per gallon of it has been the average treatment dosage. How many gallons of water can be treated with the 25 pounds of alum?

$$\begin{aligned}\text{Gal of H}_2\text{O} &= \frac{\text{lb of chem} \times 7,000}{\text{GPG}} \\ &= \frac{25 \times 7,000}{10} \\ &= 17,500 \text{ gal of water}\end{aligned}$$

## 9. Calculating Grains Per Gallon of Soda Ash or Alum Present in a Treatment Tank

a. *Formula.*

$$\text{GPG} = \frac{\text{lb of chem} \times 7,000}{\text{gal of water}} \quad (\text{see example 7})$$

b. *Illustrative Problem.* If 5 pounds of alum were put into 700 gallons of water, how many GPG's of alum are present?

$$\begin{aligned}\text{GPG} &= \frac{\text{lb of chem} \times 7,000}{\text{gal of water}} \\ &= \frac{5 \times 7,000}{700} \\ &= 50 \text{ grains per gallon of alum}\end{aligned}$$

## 10. Calculating the Marks of Alum and Soda Ash

a. *Formula (alum).*

(1)  $\text{Mk of alum} = \text{lb of alum} \times 10$

(2) Mk of alum = the marks or liquid ounces of water to be displaced by the pounds of alum or soda ash.

(3) 10: 1 pound of alum will displace 10 marks or liquid ounces of water.

b. *Formula (soda ash)*

(1)  $\text{Mk of soda ash} = \text{lb of soda ash} \times 6.7$

(2) 6.7: 1 pound of soda ash will displace 6.7 marks or liquid ounces of water.

c. *Illustrative Problem.* It has been calculated that 5 pounds of

alum and 3 pounds of soda ash are needed to treat 3,000 gallons of water. How many marks of alum and soda ash will be needed?

$$\begin{aligned}\text{Mk of alum} &= \text{lb of alum} \times 10 \\ &= 5 \times 10 \\ &= 50 \text{ marks of alum}\end{aligned}$$

$$\begin{aligned}\text{Mk of soda ash} &= \text{lb of soda ash} \times 6.7 \\ &= 3 \times 6.7 \\ &= 20.1 \text{ mk of soda ash}\end{aligned}$$

## 11. Calculating Pounds of Chlorine

a. *Formula.*

$$(1) \text{ Lb of Cl}_2 = \frac{\text{Gal of H}_2\text{O} \times 8.3 \times \text{PPM}}{1,000,000}$$

$$(2) \text{ Lb of Cl}_2 = \text{pounds of chlorine}$$

$$(3) 8.3 = \text{the weight in pounds of 1 gallon of water}$$

$$(4) \text{ PPM} = \text{the actual dosage of chlorine in parts per million (PPM)}$$

$$(5) 1,000,000 = \text{a constant}$$

b. *Illustrative Problem.* If 8 PPM chlorine are required for 3,000 gallons of water, how many pounds of chlorine will be required?

$$\begin{aligned}\text{Lb of Cl}_2 &= \frac{\text{Gal of H}_2\text{O} \times 8.3 \times \text{PPM}}{1,000,000} \\ &= \frac{3,000 \times 8.3 \times 8}{1,000,000} \\ &= 0.1192 \text{ lb of chlorine}\end{aligned}$$

## 12. Calculating Gallons of Water That Can Be Treated With a Certain Supply of Chlorine on Hand

a. *Formula.*

$$\text{Gal of H}_2\text{O} = \frac{\text{lb of Cl}_2 \times 1,000,000}{8.3 \times \text{PPM}} \quad (\text{see example 11})$$

b. *Illustrative Problem.* There are 4.15 pounds of chlorine on hand and the operator has been using 5 PPM chlorine as the average treatment dosage. How many gallons of water can the operator treat before he runs out of chlorine?

$$\begin{aligned}\text{Gal of H}_2\text{O} &= \frac{\text{lb of Cl}_2 \times 1,000,000}{8.3 \times \text{PPM}} \\ &= \frac{4.15 \times 1,000,000}{8.3 \times 5} \\ &= 100,000 \text{ gal of water}\end{aligned}$$



### 13. Calculating the Parts Per Million Chlorine Present in a Treatment Tank

#### a. Formula.

$$\text{Ppm} = \frac{\text{lb of Cl}_2 \times 1,000,000}{\text{gal of H}_2\text{O} \times 8.3} \quad (\text{see example 11})$$

b. *Illustrative Problem.* If 16.6 pounds of chlorine were added accidentally to 20,000 gallons of water, how many PPM chlorine are present?

$$\begin{aligned} \text{Ppm} &= \frac{\text{lb of Cl}_2 \times 1,000,000}{\text{gal of H}_2\text{O} \times 8.3} \\ &= \frac{16.6 \times 1,000,000}{20,000 \times 8.3} \\ &= 100 \text{ PPM chlorine} \end{aligned}$$

### 14. Calculating Ounces of Calcium Hypochlorite

#### a. Formula.

$$(1) \text{ Oz Ca (OCl)}_2 = \text{lb of Cl}_2 \times 22.9$$

(2) Oz = ounces of calcium hypochlorite

(3) Ca (OCl)<sub>2</sub> = the chemical symbol for calcium hypochlorite

(4) 22.9: a constant—it takes 22.9 ounces of calcium hypochlorite to equal 1 pound of pure chlorine gas.

b. *Illustrative Problem.* It has been determined that 0.5 pounds of chlorine will be required to treat a water source. How many ounces of Ca (OCl)<sub>2</sub> will be required?

$$\begin{aligned} \text{Oz Ca (OCl)}_2 &= \text{lb of Cl}_2 \times 22.9 \\ &= 0.5 \times 22.9 \\ &= 11.45 \text{ ounces of Ca (OCl)}_2 \end{aligned}$$

## APPENDIX IV

### WATER SUPPLY CHECKLISTS

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#### **1. Checklist for Water Reconnaissance**

Information on the following items must be obtained and recorded:

- a.* Quantity available.
- b.* Quality.
  - (1) Color.
  - (2) Odor.
  - (3) Turbidity.
  - (4) Taste.
  - (5) Possible sources of pollution.
  - (6) Condition of vegetation.
  - (7) pH value.
  - (8) Chlorine demand.
  - (9) Test for chemical warfare agents.
- c.* Routes of communications.
  - (1) Condition of roads.
  - (2) Extent of road net.
  - (3) Traffic circulation.
- d.* Site conditions.
  - (1) Cover and concealment.
  - (2) Possible aerial and artillery targets.
  - (3) Drainage.
  - (4) Bank conditions.
  - (5) Access roads and parking areas.
  - (6) Bivouac area for operators.
- e.* Work estimate.

#### **2. Checklist for Development of Water Points**

The following list of questions is helpful in planning developments:

- a.* Has the area been reconnoitered for a point requiring fewer improvements?
- b.* Does the source yield enough clear water?

*c.* Are all spillage areas, especially the loading area, well drained?

*d.* Are all tanks and equipment level and off the ground?

*e.* Are there enough storage tanks to handle peak loads?

*f.* Can the treated water be safely and quickly distributed?

*g.* Will dry points eliminate distribution problems?

*h.* Should a pipeline be used?

*i.* Is the water point well camouflaged?

*j.* Is the treatment-equipment layout correct?

*k.* Are the water-point records adequate?

*l.* Is the bivouac area adequate for personnel?

*m.* Is latrine located at least 100 yards from and downhill from water point?

*n.* Have shelters been provided for protection against the possible use of nuclear weapons?

## APPENDIX V

### COMPUTATION OF CALCIUM HYPOCHLORITE REAGENT

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The calcium hypochlorite test reagent is standardized so that 1 ml added to 1,000 ml of water will be equivalent to a 5 ppm  $\text{Cl}_2$  test dosage. The use of this reagent is described in paragraph 88b (1).

5 ppm might also be written as  $= \frac{5}{1,000,000}$

$$\frac{1,000 \text{ cc H}_2\text{O}}{1 \text{ cc sol}} \times \frac{5 \text{ gm Cl}_2}{1,000,000 \text{ gm H}_2\text{O}} = \frac{5,000}{1,000,000}$$

5,000 ppm  $\text{Cl}_2$  should therefore be the concentration of the test reagent if 1 milliliter is to impart a 5 ppm  $\text{Cl}_2$  test dosage to 1,000 cc of  $\text{H}_2\text{O}$ .

Calcium hypochlorite is only 70% available chlorine:

gm  $\text{Cl}_2$  : % strength :: xgm  $\text{Ca}(\text{OCl})_2$  : 100% (pure  $\text{Cl}_2$ )

5 gm  $\text{Cl}_2$  : 0.70 :: X gm  $\text{Ca}(\text{OCl})_2$  : 1.00

5 : 0.7 :: X : 1                      0.7 X = 5

X = 7.14 gm  $\text{Ca}(\text{OCl})_2$  or

7.14 gm  $\text{Ca}(\text{OCl})_2$  equals 5 gm  $\text{Cl}_2$  gas.

To weigh 7.14 gm of  $\text{Ca}(\text{OCl})_2$  in the field would be extremely impractical, as the water supply specialist does not have access to a chemical balance. The problem is solved by "weighing" the calcium hypochlorite by water displacement method.

Calcium hypochlorite has a specific gravity of 1.525 as compared with water at 1.000. Here again ratio may be used to determine how much water would be displaced by 7.14 gm of calcium hypochlorite.

$$\frac{7.14 \text{ g Ca}(\text{OCl})_2}{X \text{ g H}_2\text{O}} = \frac{1.525 \text{ spg Ca}(\text{OCl})_2}{1.0 \text{ sp gr H}_2\text{O}}$$

$$1.525 X = 7.14$$

$$X = 4.7 \text{ gm H}_2\text{O}$$

It is seen that 7.14 gm  $\text{Ca}(\text{OCl})_2$  will displace 4.7 gm of water. Since a gram of water occupies 1 milliliter of space, displacing slightly over  $4\frac{1}{2}$  cc of water with  $\text{Ca}(\text{OCl})_2$  will give 7.14 gm

of the powder. By mixing this quantity of  $\text{Ca}(\text{OCl})_2$  with 1,000 cc of water, a 5,000 ppm  $\text{Cl}_2$  solution has been made.

This solution must be rapidly agitated in its preparation so as to get maximum disassociation of the calcium hypochlorite. After preparation, the solution should be kept in a dark bottle and out of direct sunlight. Even with these precautions, the test reagent should be prepared fresh each week for maximum effectiveness.

One milliliter of this standard reagent, when added to 1,000 cc of the water to be tested, equals a 5 ppm  $\text{Cl}_2$  test dosage.

If 1 ml solution equals 5 ppm  $\text{Cl}_2$ , it is seen that any proportionate test dosage may be used:

$$\begin{aligned} 5 \text{ ppm} : 1 \text{ ppm} &:: 1 \text{ ml} : x \text{ ml} \\ 5 X &= 1 \text{ or } X = 0.2 \text{ ml} \end{aligned}$$

For each 0.2 ml calcium hypochlorite reagent added to 1,000 cc  $\text{H}_2\text{O}$  to be tested, we have 1.0 ppm  $\text{Cl}_2$ .

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By Order of the Secretary of the Army:

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*General, United States Army,  
Chief of Staff.*

Official:

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*Major General, United States Army,  
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For explanation of abbreviations used, see AR 320-50.

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